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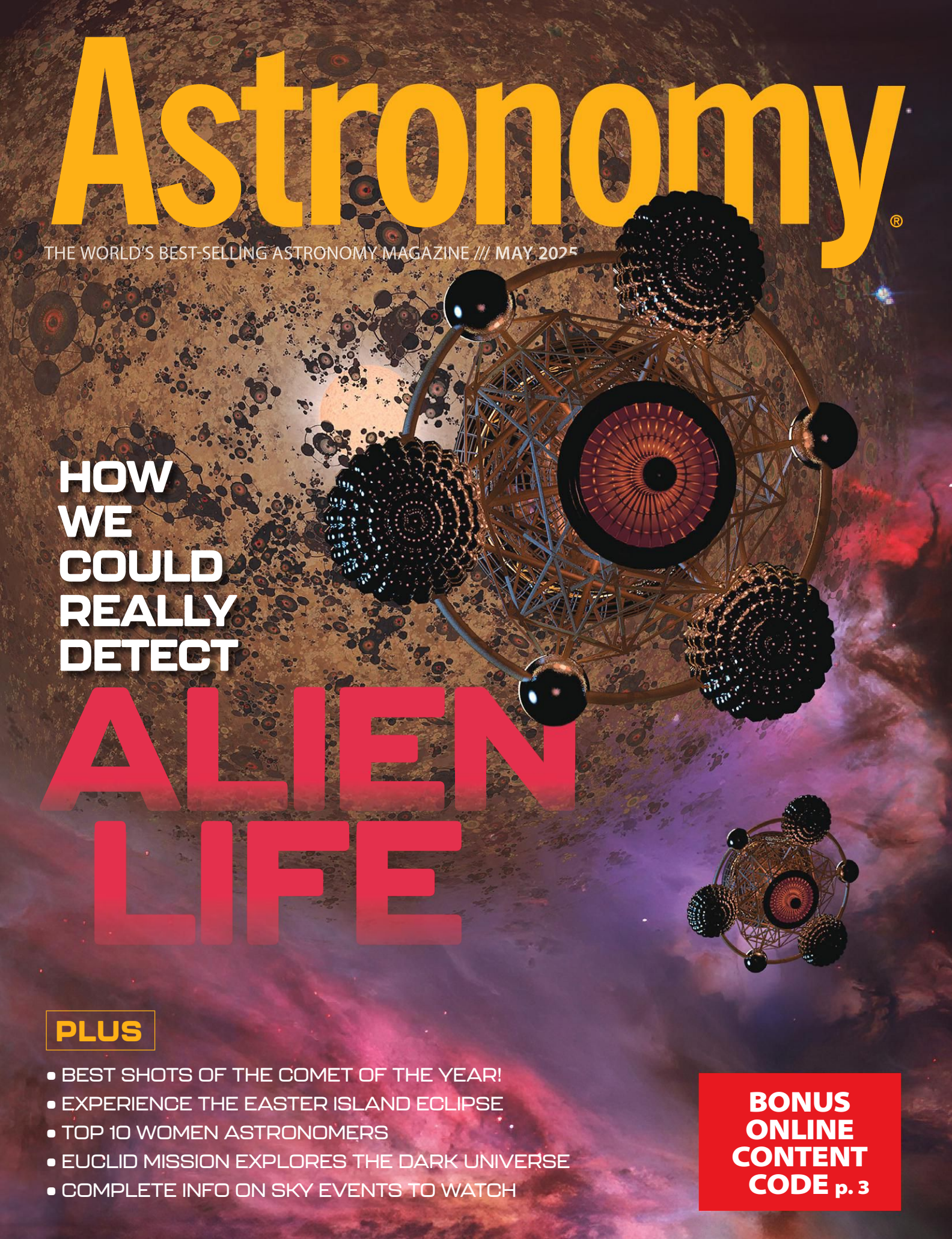

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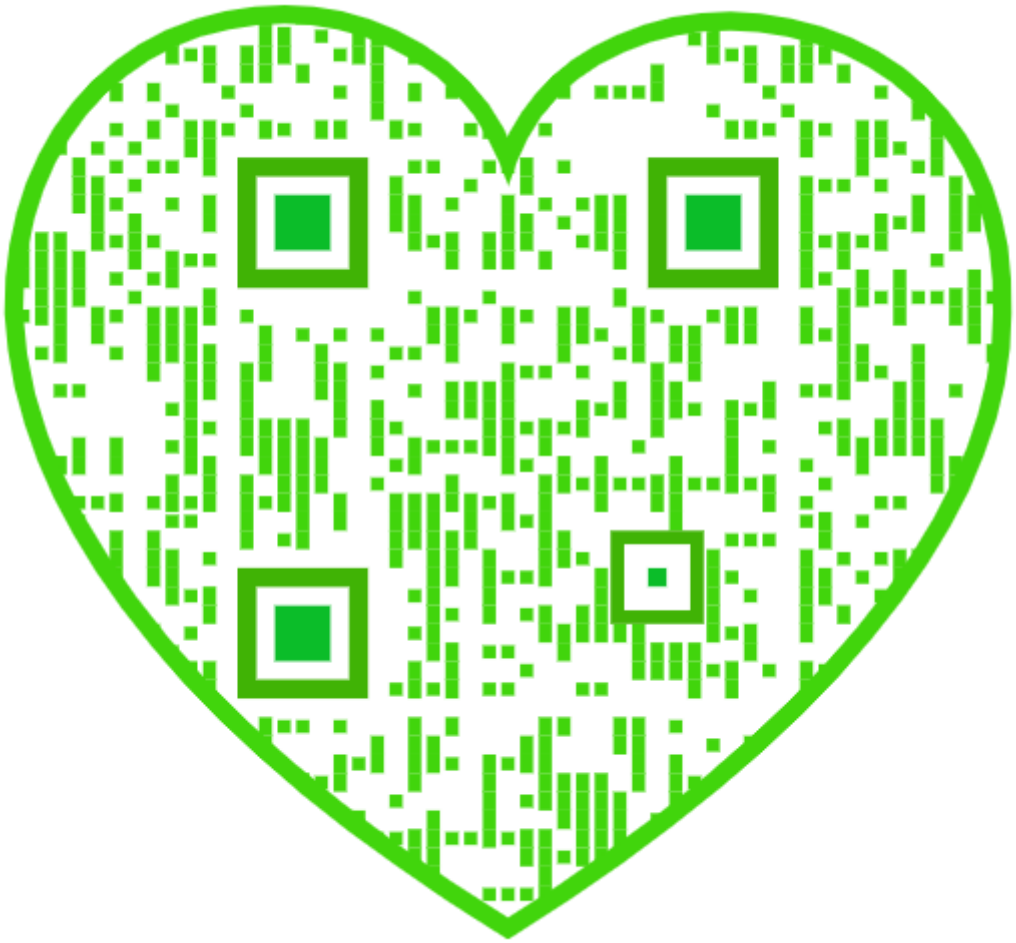

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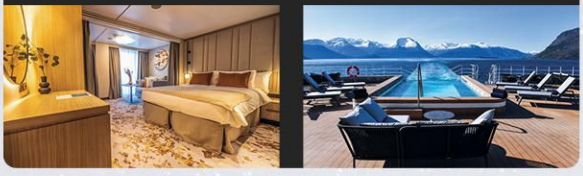

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CONTENTS

MAY 2025
VOL. 53, NO. 5

ON THE COVER

Dyson spheres — swarms of satellites like those illustrated here — are just one example of theoretical infrastructures whose discovery could lead us to alien life. DON DIXON

FEATURES

14 COVER STORY
Can we detect alien artifacts?
SETI's senior astronomer explains how colossal artifacts could be the key to finding ET.
SETH SHOSTAK

20
The comet of the year
Comet Tsuchinshan-ATLAS treated stargazers in both hemispheres to an impressive display. **MARK ZASTROW**

26
Euclid captures billions of galaxies
Europe's new space telescope will create a 3D map of the cosmos to explore the effects of dark energy. **KOREY HAYNES**

28
Sky This Month
The Red Planet pokes the Beehive.
MARTIN RATCLIFFE AND ALISTER LING

30
Star Dome and Paths of the Planets
RICHARD TALCOTT; ILLUSTRATIONS BY ROEN KELLY

36
Eclipse success on Easter Island
This spectacular locale presented a stunning dark sky, a famous comet, and the main event — an annular eclipse.
DAVID J. EICHER

40
10 women who changed astronomy
Often bucking tradition, these women sought knowledge of the universe and reimagined the way we view the cosmos.
SAMANTHA HILL

50
Ask Astro
Messier's 102nd object.

COLUMNS

Secret Sky 12
STEPHEN JAMES O'MEARA

Observing Basics 48
MOLLY WAKELING

IN EVERY ISSUE

From the Editor 4
New Products 49
Advertiser Index 49
Reader Gallery 54
Breakthrough 58

7 QUANTUM GRAVITY
Everything you need to know about the universe this month: a nearby galaxy bursts forth with stars, "little red dots" stump astronomers, an asteroid hosts elements of life, and more!

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Finding life in the cosmos

The search for other civilizations is an extremely tricky exercise. ALEX SAVELLO/NRAO

Of the countless stars and planets that must exist in the cosmos, we know of life on only one — our Earth. But the emerging scientific knowledge of the last generation teaches is that life must be spread all over the universe. So, as the so-called Fermi Paradox states, if they're out there, why haven't we found them?

The answers are many. Let's start with the odds. We know of nearly 6,000 planets orbiting stars other than ours in the Milky Way. And we are in the early days of technologically discovering and cataloging planets so far away. We know the Milky Way contains several hundred billion stars — the exact number is hard to decipher because the most numerous stars, M dwarfs, are hard to detect over long distances due to their faintness. And we know that at least something like 100 billion galaxies exist, and perhaps — as strange as it sounds — the universe might even be infinite. There ought to be lots of life out there, but it is likely incredibly hard to find.

Spectroscopy tells us that chemistry is uniform throughout the cosmos, and we have found interesting precursor molecules to life, like amino acids, in comets. The stuff of life seems to be spread everywhere in the universe. So why haven't we found other intelligent beings? Or even super-simple life elsewhere than Earth?

For several reasons. It's really hard to do, even if lots of life, even lots of civilizations, are out there. Detecting electromagnetic radiation from another civilization is tough because you have to be "listening" at the right frequency and at the right time, and such energy doesn't travel forever through the cosmos.

But astronomer Seth Shostak of the SETI Institute, the very person who would likely first know of another civilization, offers another way in this issue. He writes about the possibility of finding technological signs of another living group. I hope Seth's story (page 14) will fill you with hopes and dreams of what may be one of the biggest discoveries in world history when we make it.

Yours truly,

David J. Eicher
Editor-in-Chief

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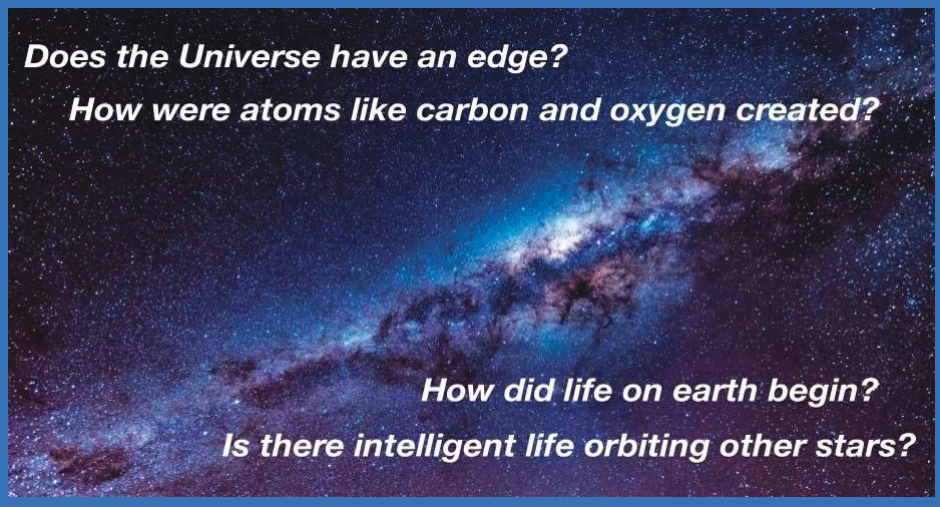
Does the Universe have an edge?
How were atoms like carbon and oxygen created?
How did life on earth begin?
Is there intelligent life orbiting other stars?

Dr. George Roush will explore

1. Geo-centrism & the Copernican Revolution
2. Our sun & its planets
3. The birth, evolution & death of stars
4. Telescopes
5. Our Milky Way Galaxy
6. Other galaxies & their evolution
7. Dark matter: What is it?
8. Dark energy & the expanding universe
9. Relativity & black holes
10. The Big Bang: The beginning of spacetime
11. Is intelligent life orbiting other stars?

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SNAPSHOT

BURSTING WITH STARBIRTH

JWST's colorful view shows a molecular cloud complex in the Large Magellanic Cloud.

Located in the Large Magellanic Cloud (LMC), N79 South is part of a vast 1,630-light-year-wide region filled with molecular clouds and burgeoning stars. In this image, JWST's Mid-Infrared Instrument (MIRI) reveals blue wisps made of ionized hydrogen gas and cooler dust. The spikes extending from the top-center portion of the image are an artifact that results from JWST's 18 hexagonal mirrors.

JWST found that N79 hosts a so-called super star cluster of forming suns just 100,000 years old. It is the second such cluster found in the LMC, matching the Milky Way's own count. These clusters, abundant billions of years ago, offer glimpses of how stars formed in a younger universe. The MIRI data show that the most massive protostars have "sunk" to the center of the cluster, and also reveal that one presumed single protostar is actually five distinct stars — one of which blazes more than 500,000 times brighter than the Sun. –SAMANTHA HILL, ALISON KLESMAN

ESA/WEBB, NASA & CSA, M. MEIXNER. BOTTOM FROM LEFT: DECALS/DESI LEGACY IMAGING SURVEYS/LBNL/DOE & KPNO/CTIO/NOIRLAB/NSF/AURA; IMAGE PROCESSING: TA. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF NOIRLAB), M. ZAMANI (NSF NOIRLAB) & D. DE MARTIN (NSF NOIRLAB); SPACEX; BLUE ORIGIN; NASA, ESA, CSA, STSCI, CHRISTA DECOURSEY (UNIVERSITY OF ARIZONA), JADES COLLABORATION

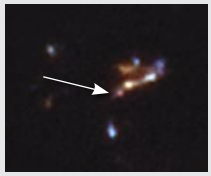
HOT BYTES

GALACTIC GHOST TOWNS

Astronomer David Sand uncovered by eye three previously unknown ultra-faint dwarf galaxies in the constellation Sculptor. These tiny "dead" galaxies long ago stopped forming stars because they couldn't hold on to the material needed for new suns.

SPACE-OFF

On Jan. 16, Blue Origin's New Glenn rocket (right) reached orbit on its first test flight. Later that day, SpaceX's Starship upper stage (left) exploded during its seventh flight, requiring some commercial planes to divert due to falling debris.



DISTANCE RECORD

JWST spotted the most distant core-collapse supernova, created by a dying star when the cosmos was just 1.8 billion years old. Studying such events allows astronomers to better understand conditions in the early universe.

‘LITTLE RED DOTS’ ARE STILL A BIG MYSTERY

These massive objects in the early universe are upending our timeline of when the first galaxies formed.

On Jan. 14, at the 245th meeting of the American Astronomical Society in National Harbor, Maryland, astronomers revisited some recent mysteries. Dale Kocevski of Colby College in Maine, spoke about the “little red dots” (LRDs) found by the James Webb Space Telescope (JWST). These are the same as the “universe-breaking” galaxies first reported roughly two years ago, so called because they are larger than scientists can explain at so early a point in cosmic time — less than a billion years after the Big Bang.

DISTANT GLOW. JWST acquired these images of little red dots. Their redshifts (denoted by the letter *z*) indicate their distance, and thus the age of the universe when they were spotted. This encompasses from when the universe was about 1.2 billion years old (z = 4.75) to just about half a billion years old (z = 8.92). NASA/ESA/CSA/STSCI/DALE KOCEVSKI (COLBY COLLEGE)

ASTRONOMY REELS UNDER TRUMP ONSLAUGHT

THE FIELD OF ASTRONOMY was gripped by chaos and uncertainty in the weeks following Donald J. Trump’s return to the U.S. presidency on Jan. 20, as he and advisor Elon Musk launched a full-scale assault on federal spending, purged the civil services of diversity initiatives, and executed mass layoffs. The blitz included a flurry of executive orders and efforts by Musk and allies at the Department of Governmental Efficiency (DOGE), an organization under the presidential executive office. Affected agencies included NASA and the National Science Foundation (NSF), which underwrite nearly all publicly funded astronomy in the U.S. Both agencies have halted key review and advisory processes.

On Jan. 27, the Office of Management and Budget (OMB) issued a memo freezing all federal loans and grants, halting paychecks for NSF-funded researchers. The memo was blocked by a court order the next day, and rescinded the day after. But after the Trump administration said the federal funding freeze was still in effect, a second court ruling issued a temporary restraining order. NSF said Jan. 31 that it had reactivated its payment portal.

One executive order directed the termination of funds and activities that promote diversity and equity. As a result, diversity offices and employee resource groups across government agencies — including NASA’s — were shuttered.

NSF is reviewing all grants, flagging awards that contain any of a list of keywords, including *women*, *inclusive*, and *marginalized*, reported *Nature*. It is unclear what will happen to grants flagged in this review. NSF is mandated by Congress to consider “broader impacts” in grant awards to achieve goals that include increasing participation of women and underrepresented minorities in STEM.

NASA employees were told to “drop everything” to scrub the agency’s website of mentions of diversity, women in leadership, Indigenous people, and environmental justice, the independent journalist-founded media website *404 Media* reported. In a move first reported by *ProPublica*, NSF’s Vera C. Rubin Observatory edited its online biography of its namesake to remove mention of her advocacy for women in science.

A Feb. 6 open letter to NASA leadership and elected representatives signed by over 700 U.S. space scientists called the diversity purge and its impacts “immensely disappointing” and warned it would threaten NASA’s ability to recruit the workforce needed to maintain U.S. leadership in space exploration. — MARK ZASTROW

Scientists simply don't understand how so many stars and so much material could accumulate in so little time. When the news first broke, there were six of these objects. Now, JWST has revealed 341 of them. Kocevski's update to the LRD investigation has been accepted for publication in *The Astrophysical Journal*.

STRENGTH IN NUMBERS

While the earlier findings are not in question, the sheer number now reported has changed the scientific perspective: These can no longer be thought of as quirks or outliers. Instead, they make up 1 out of every 5 to 10 galaxies in the early cosmos, making them routine. That ups the pressure to understand them, and only emphasizes the gathering suspicion that our understanding of galaxy assembly, at least at the dawn of cosmic time, is incomplete.

Kocevski's team was able to further probe the brightest of these objects and confirm that most — 81 percent of this subset — are active galactic nuclei, or AGN. That means they have central black holes that are actively gobbling material, causing the centers of these galaxies to glow brighter than all their stars can account for.

BRIGHT BLACK HOLES

If most LRDs are AGN, that can explain much of their universe-breaking reputation. AGN far outshine normal galaxies of the same size, so it could mean they are more moderately sized after all. But even so, there are far more of them — 10 to 100 times more — than other surveys have indicated, whether they are quasars (the brightest class of AGN), more middling AGN, or some other form of active black hole.

What's more, these galaxies only appear in the early universe. They disappear from surveys around a redshift of 4, a time when the universe was less than 2 billion years old. It's very likely that they evolve into more typical galaxies — but even that tells us something strange is happening in those early days to produce these phenomena. The LRD mystery goes hand-in-hand with other findings by JWST that perhaps the young universe didn't unfold the way we thought. – KOREY HAYNES

RIGHT-HAND MAN. SpaceX founder Elon Musk (pictured here Feb. 11 with his son in the Oval Office) has forged a close relationship with U.S. President Donald Trump, styling himself as Trump's chief executive officer. THE WHITE HOUSE

QUICK TAKES

PARIS LIMIT BREACHED

Earth's average temperature in 2024 was more than 1.5 C (2.7 F) warmer than in the preindustrial period, international climate-science groups announced Jan. 10. It is the first time Earth has surpassed the 1.5 C limit of warming set as a goal in the 2016 Paris Agreement.

LOS ANGELES ABLAZE

The Eaton fire, sparked Jan. 7 in the Altadena hills, crept within blocks of NASA's Jet Propulsion Laboratory (JPL) and, 5 miles (8 km) to the east, up to the doorstep of historic Mount Wilson Observatory. Firefighters saved both institutions, but over 200 JPL employees lost their homes.

MEET CUTE

Pluto may have acquired its largest moon, Charon, after a grazing collision, suggests a modeling study published Jan. 6. In this "kiss and capture" scenario, the pair survived their collision mostly intact and rotated together as a contact binary before receding to their current orbits.

DARK-SKY THREAT

Chile's Paranal Observatory — home to the world's darkest skies and the Very Large Telescope — is under threat by plans announced Dec. 24 by a local subsidiary of U.S. power company AES to build a massive renewable energy-powered hydrogen plant as close as 3 miles (5 km) away.

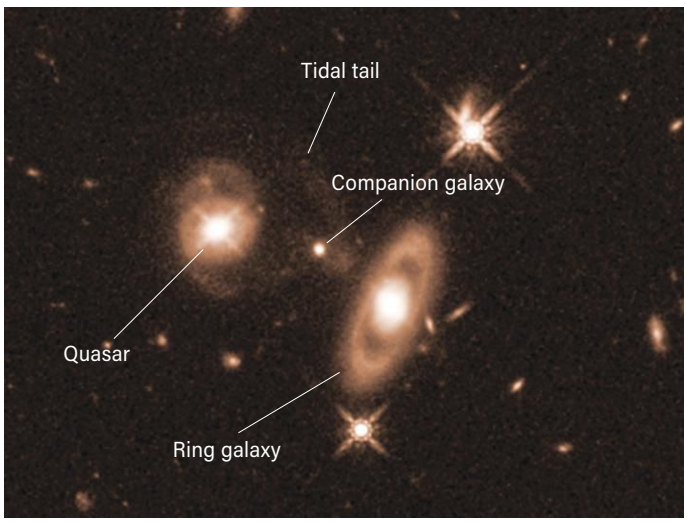
MYSTERIOUS BURST

A fast radio burst (FRB) has been found in an old elliptical galaxy, challenging the theory that such events come from magnetars — fast-rotating neutron stars. Magnetars should have slowed down in such an ancient galaxy, which suggests there may be multiple ways to produce FRBs.

NEWFANGLED BANNER

China is developing a flag that can wave on the airless Moon for the robotic Chang'e 7 mission, set to land in 2026, reports state media. The design, proposed by elementary students in Changsha, uses closed-loop wires and electromagnetic field interactions to cause the flag to flutter. – M.Z.

Unusual spiral quasar defies theory



TWO TO TANGO. The quasar J0742+2704 is flanked by a small companion galaxy and a ring galaxy in this Hubble Space Telescope image. There are also hints of a tidal tail running from J0742+2704 to its smaller companion. NASA, ESA, KRISTINA NYLAND (U.S. NAVAL RESEARCH LABORATORY). IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI)

AMONG THE MENAGERIE of galaxies, astronomers have found an example of an unusual breed: a quasar with spiral arms.

Quasars are galaxies whose central black holes produce jets that shine brighter than the rest of the galaxy itself. Typically, these galaxies are old and elliptical, having lost their spiral structure through mergers with other galaxies.

But when astronomer and U.S. Naval Academy midshipman Olivia Achenbach analyzed Hubble Space Telescope data of the quasar J0742+2704, she saw clear spiral arms — suggesting it hasn't experienced a major merger. A check of archival data revealed the jets have turned on within the past 20 years.

This doesn't jibe with the dominant theory that black holes begin feeding and launching jets when their host galaxies merge, which causes stars, gas, and dust to fall toward the central black holes. Instead, J0742+2704's jets may have been triggered by interactions with a smaller companion galaxy visible in the Hubble image.

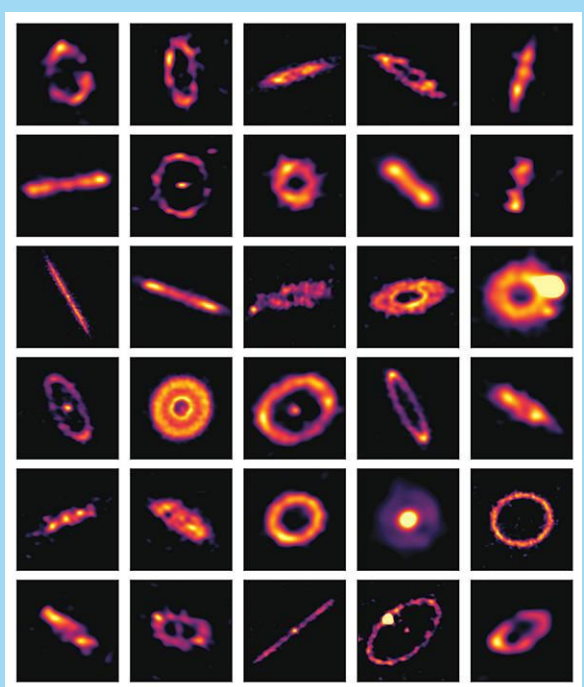
Supporting this idea, the Low-Frequency Array radio telescope network found distant lobes of emission — evidence of previous ejections. This suggests the jets turn on and off repeatedly as the companion galaxy orbits J0742+2704 in what Achenbach calls a "cosmic dance," stirring up material that falls toward the central black hole. She reported the work at the American Astronomical Society's winter meeting in January.

"To have such a clear, unambiguous result that seems to defy the major merger model is extremely exciting," says Rachel Cionitti, an astronomer at the University of Missouri-Kansas City, who wasn't involved in the study. The finding suggests there may be multiple ways for galaxies' central black holes to become active, she says. – M.Z.

ALIEN COMET BELTS COME INTO FOCUS

This mosaic shows 30 of 74 recently discovered exocometary belts — swaths of rocky, icy material left over after planet formation — around nearby stars. They were discovered by the REsolved ALMA and SMA Observations of Nearby Stars (REASONS) survey, which uses the Atacama Large Millimeter/submillimeter Array and the Submillimeter Array radio observatories. These observatories pick up light from roughly millimeter-sized "pebbles" in the belts, which lie at distances from their stars that are some tens to hundreds of times the distance of Earth from the Sun. At those locations, temperatures range from –240 to –420 degrees Fahrenheit (–150 to –250 degrees Celsius) and volatile compounds like water and carbon dioxide are present only as ices. These are the reservoirs from which most comets originate.

According to the researchers conducting the survey, exocometary belts are seen around at least 20 percent of stars with planetary systems, including our own solar system's Kuiper Belt. These belts come in a variety of sizes and morphologies, from single rings to disks with tracks carved out — regions where forming planets may lurk. Studying these belts and how they evolve will help show how planets, asteroids, and comets form and create the multitude of planetary systems we see throughout the galaxy today. – A.K.



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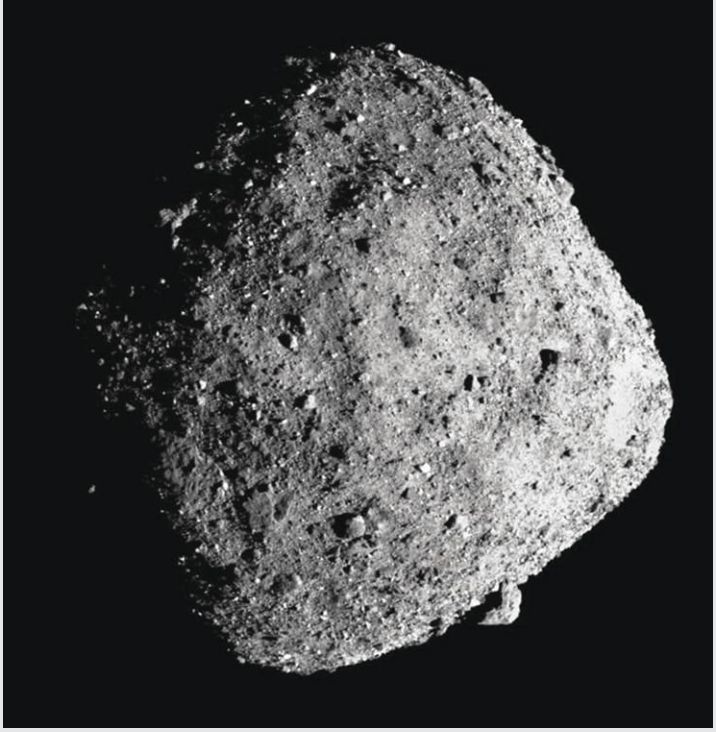

BIOLOGISTICS. Asteroids like 101955 Bennu — seen here in a mosaic of images captured by the OSIRIS-REx spacecraft — may have delivered the ingredients of life to Earth. NASA/GODDARD/UNIVERSITY OF ARIZONA

Bennu has life's building blocks

IN 2023, the OSIRIS-REx spacecraft returned to Earth with 4.3 ounces (121.9 grams) of precious material from asteroid 101955 Bennu. On Jan. 29, NASA announced that these samples have shed light on the history of water and the chemical ingredients of life in the solar system, as detailed by two research teams in separate *Nature* papers released that day.

The samples contained 14 of the 20 amino acids that make up biological proteins, along with 19 nonbiological amino acids and the five nucleobases that form RNA and DNA. Scientists also found a surprising amount of ammonia, which can react with formaldehyde (also present) to create many amino acids. While these aren't signs of life itself, they are the molecules that life uses as its fundamental building blocks. Their presence lends strong support to the theory that such materials were delivered to Earth by asteroids like Bennu.

The teams also discovered evidence of clays and brines — substances formed by the evaporation of water. Asteroids like Bennu's parent body probably formed directly from the accumulation of icy rocks. At some point, that ice must have melted, as water is necessary to form many of the materials found on Bennu. But the brines show that the water later evaporated.

Perhaps counterintuitively, this loss of water was also important: It was only as the water disappeared that some of the chemistry became possible to create the materials that one day might be incorporated by life.

One intriguing mystery emerged involving the "handedness" of molecules. Many molecules are chiral, meaning their shape can take one of two mirrored forms, left-handed or right-handed. Life on Earth strongly prefers left-handed molecules, but Bennu's samples showed an equal mix of left- and right-handed molecules. If Bennu is indeed representative of the carriers of the ingredients of life, then the question of why life prefers lefties remains a mystery. — K.H.

Because telescopes are for one-eyed pirates

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I spy five exoplanet hosts

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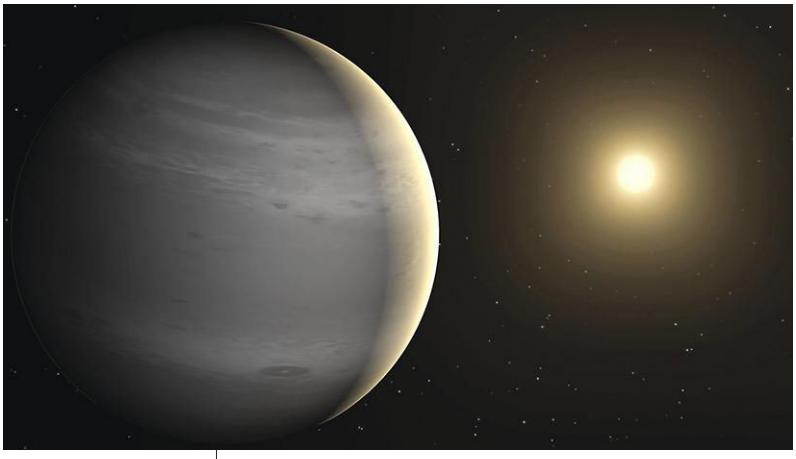

A world found by the Spitzer Space Telescope, called GJ 436 b, is proposed to contain a helium atmosphere and orbits its M-dwarf host star. NASA/JPL-CALTECH

BY STEPHEN JAMES O'MEARA
Stephen is a globe-trotting observer who is always looking for the next great celestial event.

Just a few decades ago, when we glanced skyward, we didn't know for certain whether any star visible to the naked eye hosts planets like our own. Now, NASA scientists estimate that, on average, there may be at least one planet for every star in the Milky Way. That's billions of extrasolar planets in our island universe alone — not to mention the billions of stars in the trillions of other galaxies in the cosmos.

Of the more than 5,000 exoplanets that have been confirmed so far and many more thousands of candidates, most orbit stars the mass of the Sun or lower. The spring night sky, however, offers us several examples of bright stars larger than the Sun thought to host planets. Let's look at a few and use our imaginations to envision these secret worlds.

The yellow-orange 1st-magnitude Pollux (Beta [β] Geminorum), at only 34 light-years distant, is the closest giant star to the Sun, and the brightest gem in Gemini the Twins. Slightly under 2 solar masses, Pollux may also be one of the brightest intermediate-mass stars known to host a candidate planet. Properly known as Thestias, or Pollux b, this unconfirmed gas-giant world has a minimum mass and size twice that of Jupiter. It lies 1.7 astronomical units (AU; 1 AU is the average Sun-Earth distance of 93 million miles [150 million kilometers]) away from its parent star, completing an orbit once every 590 days.

Moving eastward, 2nd-magnitude Algieba (Gamma [γ] Leonis) in the Sickle of Leo asterism lies 130 light-years distant. Algieba is actually the combined light of a binary star system: a 2nd-magnitude orange giant star (Gamma^1) and a 4th-magnitude yellow giant (Gamma^2), which orbit each other over a 510-year period. However, our interest is mainly in Gamma^1 Leonis; it has a confirmed gas-giant planet, Gamma^1 Leonis b, slightly larger in size and at least nine times the mass of Jupiter. The planet is 1.2 AU from its host and takes 428½ days to complete an orbit. A possible second companion remains unconfirmed.

Some still consider Errai to have the first discovered exoplanet.

Slipping over to the north, we find 2nd-magnitude Kochab (Beta [β] Ursae Minoris) — the brightest star in the bowl of Ursa Minor (or Little Dipper) and one of members of the ancient "guardians of the pole" asterism. Also lying 130 light-years distant, this orange giant harbors a substellar gas-giant planet, Kochab b, with a minimum mass of six Jupiters. The planet orbits its host star once every 522 days from a distance of 1.4 AU.

Still facing north, let's now turn our attention to Errai (Gamma Cephei), the star marking the rooftop of the house-shaped asterism in Cepheus the King. This orange giant star, 45 light-years away, appears as a single 3rd-magnitude star, but it is the combined light of two stars forming a true binary pair. As early as 1988, astronomers believed Errai had a planet, Gamma Cephei A b, orbiting it, but that suspicion was not confirmed until 2002. Some still consider Errai to be the star with the first discovered exoplanet. It has slightly more than nine times the mass of Jupiter and lies at an average distance of 2.1 AU from its host. This places it in the star's habitable zone, where water can exist in liquid form and life could have a possibility of taking hold — especially if the planet has a moon.

Our last extrasolar gem also resides in the north. Shining at 3rd magnitude from a distance of 100 light-years, Edasich (Iota [ι] Draconis) is an orange giant star. It's about the same mass as the Sun and hosts two confirmed worlds that may be planets. (Given the uncertainty in their measurements, there is also a possibility they are brown dwarfs.) Iota Draconis b is properly known as Hypatia (after the Greek scholar of ancient Alexandria) and weighs between 12 and 26 Jupiter masses. It lies at a distance of 1.5 AU in the star's habitable zone, swinging around its host once every 1.4 years. Edasich's second known world, Iota Draconis c, is between 12 and 30 Jupiters. It lies somewhere between 12 AU and 30 AU from its host, taking 30 to 120 years to complete one orbit — well away from the habitable zone.

The exoplanets listed above are but a small sample of the many wonders available to see.

This will be my last column for *Astronomy*, and as always I wish you well, with many starlit nights to fill your hearts with joy.

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CAN WE DETECT ALIEN AR

SETI's senior astronomer explains how colossal artifacts could be the key to finding ET.

BY SETH SHOSTAK

THERE ARE TENS OF BILLIONS of Sun-like stars in the Milky Way, an immense tally that encourages the possibility that extraterrestrial life peppers the universe. Finding evidence for aliens — even microscopic ones — would confirm the widespread belief that life is not an unlikely event, constrained to a small number of planets and moons. It could be commonplace, a ubiquitous cosmic infection.

This idea is not new. Since the time of the classical Greeks, many scholars have assumed that life was everywhere, even though they lacked the technical means to find it. By the 19th century, European novelists were writing stories about sophisticated inhabitants of our Moon, and a century later both scientists and the public were convinced that Mars was teeming with clever beings who had built massive irrigation structures visible from earthly telescopes.

Even though the idea of lunar life is now considered foolish and the belief in canals on Mars has evaporated, the hope for discovering life beyond Earth has intensified. Much of this contemporary interest is powered by our successful discovery of more than nearly 6,000 planets around other stars, and that is surely just a small sample of what's out there. With all that opportunity for life, the idea of hunting for aliens by looking for their infrastructure — artifacts, in SETI parlance — whether irrigation or power systems, surely deserves another look.

NEARBY NEIGHBORS?

Exoplanets, it turns out, are as common as garden ants. However, it might not be necessary to search even that far afield to find some cosmic company. In our solar system, astronomers recognize at least seven worlds that could have reservoirs of liquid water — places where alien microbes could exist. And in a shift of thinking that would have surprised those Victorian-era scientists so focused on arid Mars, we now consider some of the moons of the outer solar system to be our best bets for finding life within rocket range. To 19th-century astronomers, these moons appeared only as luminous dots. But we now know these modest points of light are swathed in water and ice, and may be where we'll first find life beyond our own planet.

Our searches also are less direct now than they were when the Victorians turned

A swarm of satellites — collectively called a Dyson sphere — surrounds a red dwarf sun in this artist's concept. Each satellite is envisioned with solar sails to assist with orbital maneuvers. DON DIXON

TIFACTS?

their telescopes on the Red Planet. Instead, we try to find secondary clues to the presence of biology, such as using spectroscopy to search for atmospheric gases that are the byproduct of metabolism. This approach can work for moons and planets both near and far, for teeming ecosystems or scant microbiology.

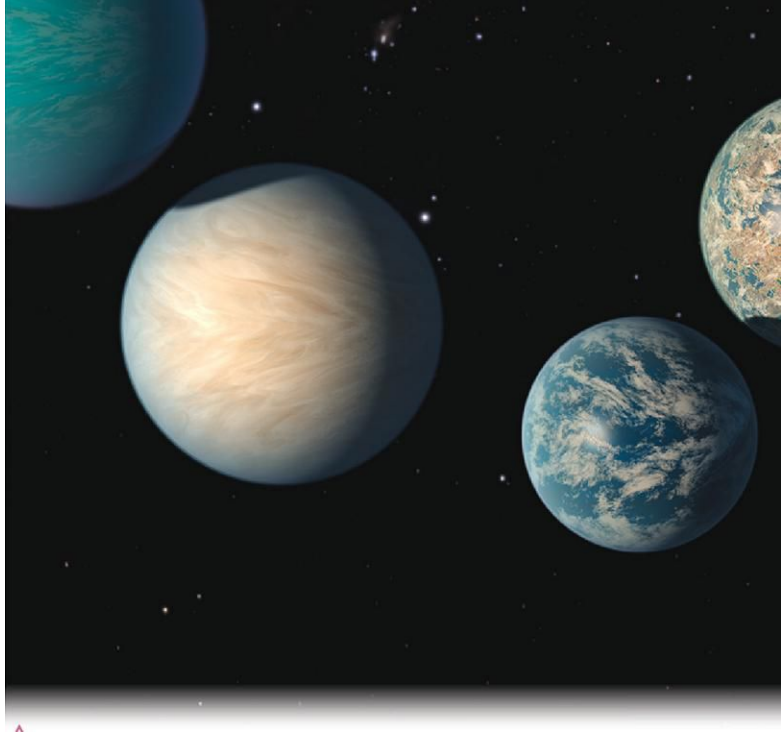
There's little doubt that finding any extraterrestrial life would be a stunning achievement. But the most interesting discovery would be to find intelligent life, which is to say organisms that can rival humans in their cognitive abilities, beings that are like the aliens in our movies and TV shows. Detecting thinking organisms would surely be one of the biggest news stories of all time, if not *the* biggest.

HOW'S IT GOING?

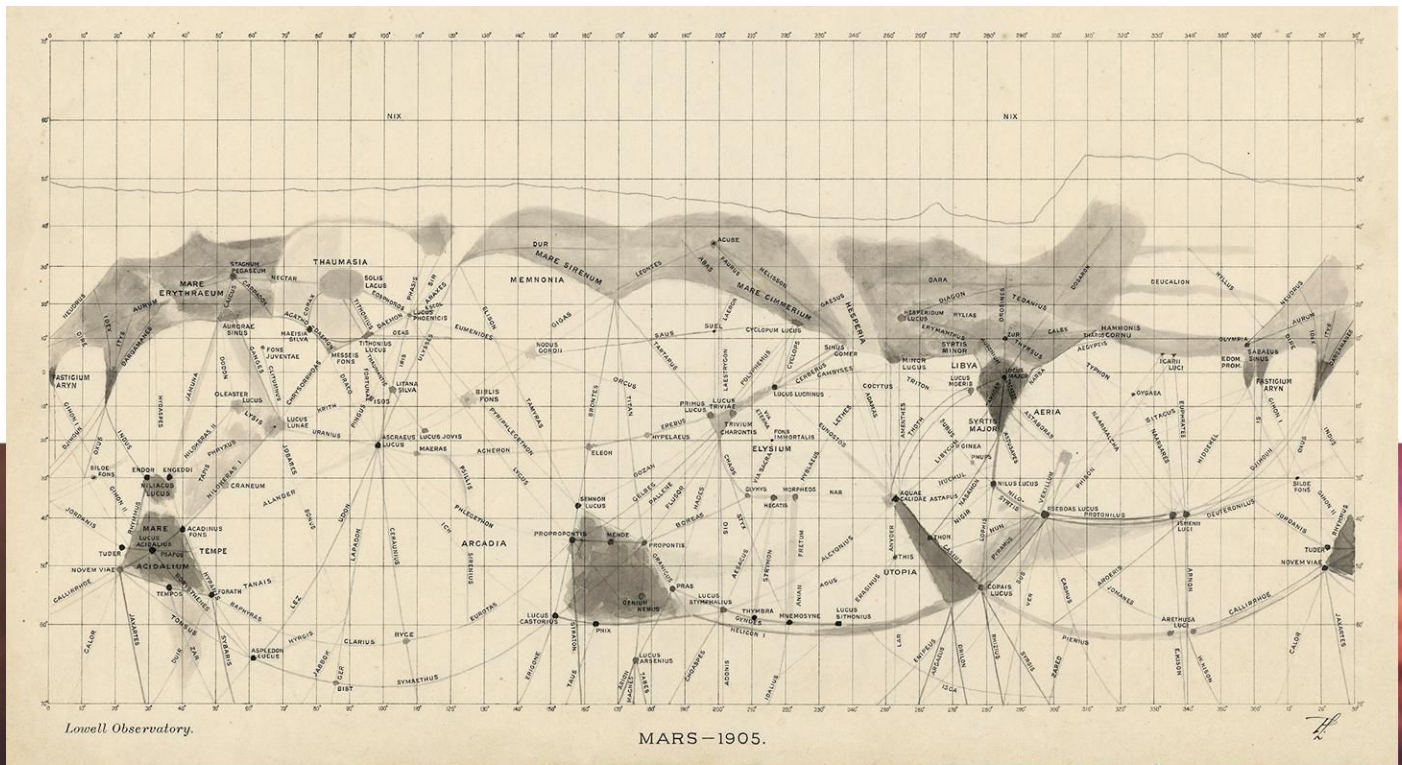
In the absence of direct contact, of course, we are limited to looking for other clues. By the time of World War II, most scientists had discounted the century-long claims of engineering projects — specifically, canals — built by thinking beings on Mars, ascribing them to optical illusions. As the Space Age got underway, flybys of the Red Planet not only failed to find such features, but revealed a desolate and seemingly sterile world.

Astronomers, undaunted, swung their instruments to more distant targets. In 1960, Frank Drake made the first modern attempt to pick up deliberate radio signals from extrasolar societies. He sequentially pointed an 85-foot-diameter (26 meters) radio telescope in West Virginia toward two nearby star systems in an endeavor known as SETI, the Search for Extraterrestrial Intelligence. He whimsically dubbed his two-week effort Project Ozma in a nod to Frank Baum's *Wizard of Oz* book series.

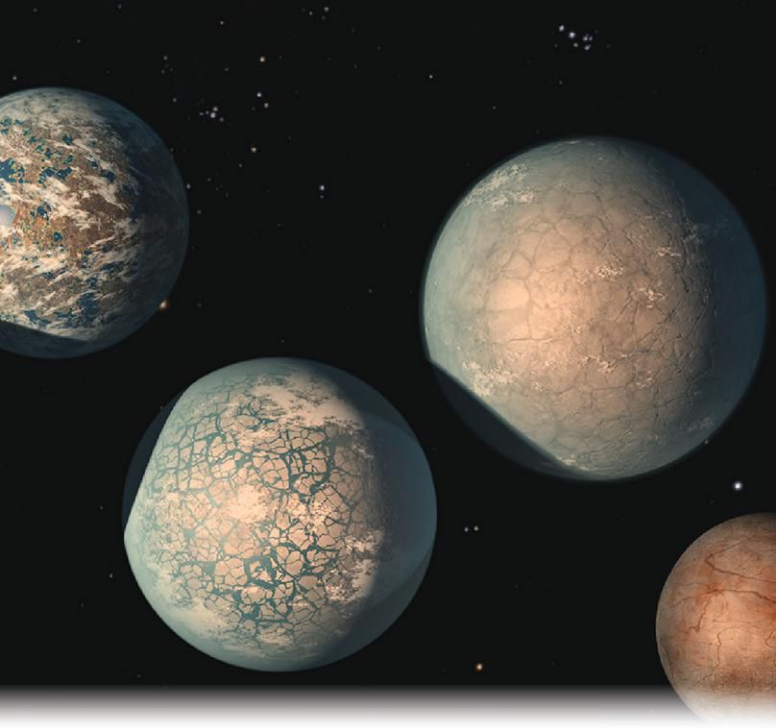
Drake didn't detect any extraterrestrial transmissions. Nonetheless, more than six decades later, radio searches remain the go-to method for trying to prove that someone is out there. Contemporary experiments are similar to Drake's and continue to use



Today, astronomers have confirmed more than 5,000 worlds of all kinds circling other stars, including the seven worlds imagined here, all of which orbit the star TRAPPIST-1. And the list just keeps growing. With so many possibilities in our galaxy alone, what might alien civilizations have left behind for us to find? NASA'S GODDARD SPACE FLIGHT CENTER



Percival Lowell's hand-drawn map of Mars, made in the opening years of the 20th century, shows the Red Planet crisscrossed with linear features he believed were canals built by an intelligent civilization. LOWELL OBSERVATORY ARCHIVES



the highly sensitive equipment of radio astronomy to search for the kind of narrowband signal that only an artificial transmitter could make.

We've still not found aliens, even though a majority of the scientific community, as well as the general public, believe they exist. Mind you, radio waves from the cosmos are commonplace, sustaining a substantial cohort of radio astronomers who study these emissions to learn about the universe. But while we've cataloged several thousand pulsars (spinning neutron stars) and more than a million quasars (feeding supermassive black holes), no signal picked up by our radio telescopes has yet had the characteristics of a deliberate broadcast.

Radio is only one technology communicating aliens might use, however. There are others: for example, flashing signals into space with lasers. Lasers can send many more bits of information per second than a radio transmitter, and consequently some advanced aliens might be using them for interstellar communication. To that end, the LaserSETI network, currently operated from roughly a dozen observatories worldwide, is designed to continually search the entire night sky for flashes of optical laser light originating beyond our solar system.

A CLASSIC IDEA

Signals are not the only kind of evidence for aliens we might find. In particular, we could look for massive artifacts, constructions large enough — or bright enough — to be detectable by our telescopes.

This is hardly a new idea; it goes back at least a half-millennium, when polymath and bishop Nicholas of Cusa suggested that all heavenly bodies were populated by plants and animals. During the Victorian era, several reputable astronomers claimed to have seen signs of intelligent beings in our own solar system. Italian astronomer Giovanni Schiaparelli and American astronomer Percival Lowell both claimed to espy straight-line markings on Mars. Lowell explained these as irrigation ditches constructed to support martian agriculture. The astronomers weren't seeing the martians themselves, of course — just their civil engineering efforts. The so-called martian canals eventually became a trope, if not a fact.

Astronomer Frank Drake utilized the 85-foot (26 m) Howard E. Tatel telescope in Green Bank, West Virginia, pictured here, for his two-week observing campaign in 1960 aimed at searching for signs of extraterrestrial intelligence. NRAO/AUI/NSF

SCALE IT UP

In 1964, Soviet astrophysicist Nikolai Kardashev published a paper in which he classified hypothetical alien civilizations by the amount of power they were capable of harnessing. His framework was later called the Kardashev Scale. Within it, Level I civilizations would be capable of utilizing a planet's worth of power, which he claimed Earth was close to already. (A 2023 *Nature* paper estimates we're at Kardashev Level 0.73 out of 3.)

Level II civilizations would be able to harness the power of their star, which both he and later researchers took to mean use of a Dyson sphere or similar technology.

Aliens with a Level III civilization would have access to power on a galactic scale, a feat that seems unimaginable until you consider that once aliens spread beyond a single planet or system, the metaphorical seal is broken. Indeed, it becomes difficult to imagine how to wipe out a fully established multiplanet species. And while we don't know what their infrastructure or communications might look like, many astronomers think it would be hard for such a civilization not to leave some kind of observable mark on the universe. *—Korey Haynes*

Public works and monuments, such as the famous pyramids of Giza in Cairo, Egypt, can far outlast their civilizations, leaving behind traces for future explorers to find. MIKHAIL KOKHANCHIKOV/DREAMSTIME.COM

Alien signals will certainly be novel and exciting, but not every signal from space is alien in origin. The regular radio blips we see from pulsars — fast-spinning neutron stars emitting beams of radiation from their poles, as imagined here — were once thought to be communications from aliens, but now have a natural explanation. NASA'S GODDARD SPACE FLIGHT CENTER

In 1960, physicist Freeman Dyson suggested another approach. He noted that technically sophisticated aliens might surround their home stars with a constellation of satellites outfitted with solar panels. This phalanx of orbiting light collectors, now termed a Dyson sphere, could capture a large fraction of the star's radiative output. This energy would then be beamed back to the aliens' home planet, powering their high-tech lifestyles with a scheme that offered an endless supply of energy and had no environmental impact. Crucially, scientists understand that these satellites would inevitably become warm, and consequently radiate a weak infrared glow that would make them visible to our telescopes.

The idea of Dyson spheres marking the location of sophisticated societies was not only ingenious, but also made a prediction that could be experimentally verified. The prediction in this case was that the satellites would produce infrared radiation. This meant that astronomers could find a Dyson sphere by noting any unexpected infrared emission from a star system.

For several decades, researchers have tried to do exactly that. Most recently, astronomers at Sweden's Uppsala Observatory surveyed 5 million stars, looking for the telltale glow of a Dyson sphere. They report finding 60 candidates that have more-than-expected infrared radiation, and are following up with additional observations.

THE ADVANTAGE OF ARTIFACTS

Searching for artifacts offers a straightforward advantage over the way SETI has historically been pursued. The traditional approach pioneered by Drake assumes that our telescopes are pointed in the aliens' direction at the same time their signal arrives at Earth.

This synchronicity requirement clearly reduces the chances of successfully eavesdropping on ET. By how much? Alas, we can't say without knowing how many societies are out there. We also need to have an idea of their typical lifetimes — how long do they signal for before they either die or are snuffed out? We don't know either of these things.

But if we hunt for artifacts instead of signals, we can largely avoid such uncertainties. Artifacts can be found at any time subsequent to their construction. The Egyptian pyramids and the American interstate highway system are

WHERE ARE ALL THE ALIENS?

Scientists in large part agree that the prospects are rich for life in the universe. Perhaps less intuitively, they've noted that given the billions of years the universe has existed, even the slowest space-faring society could still spread galaxy-wide in a few million years — the cosmic blink of an eye. So why aren't they visiting us on the regular?

This line of questioning is called Fermi's Paradox, named for Enrico Fermi, a Nobel laureate and architect of the atomic bomb who also pondered the existence of alien life along exactly these lines. While many a thought has been given to possible answers, whether while stargazing, writing a scientific paper, or staring at one's ceiling too late at night, a few theories commonly recur:

The Great Filter. While the prospects for life may be empirically good, some think that life (or perhaps multicellular life, or civilized life) actually developing is exceedingly rare. Perhaps we are a special case, though that's rarely been true any other time we've thought so throughout history.

Self-destruction. For those who look at humanity's tendency

Following in the footsteps of Frank Drake, our most current SETI efforts focus on detecting radio signals from space. The Commensal Open Source Multimode Interferometer Cluster (COSMIC) system uses the Very Large Array in Socorro, New Mexico, shown here, to search for signals while astronomers are using the array for unrelated scientific investigations. ALEX SAVELLO/NRAO

testaments to human existence that could plausibly outlive humans themselves. Even after we are long gone, these engineering projects will tell anyone who finds them that we were once here. And, as a further advantage, a hunt for artifacts doesn't depend on guessing the aliens' choice of frequency or transmitter power.

What sort of artifacts might we expect? While Dyson spheres are certainly one possibility, we can't confidently describe how an alien construction would appear any more than the first humans could accurately anticipate the appearance of a 21st-century cityscape. A fundamental challenge to any artifact hunt is that we can't be sure what we're looking for.

But it's not necessarily an insurmountable problem. We might still find these artifacts simply because they would be novel, and not already members of the known cosmic bestiary. For example, consider the aforementioned quasars. No one predicted the existence of these objects, let alone what they would look like. Indeed, both quasars and pulsars were initially suspected of being alien handiwork. We now have natural explanations for both, but they were discovered because they were different from other objects we knew about at the time.

ONLY THE BEST

Despite the fact that we can't say much about the appearance of alien artifacts, there's little doubt that any we find will be subject to selection effects. The easily detectable ones will surely be the biggest and brightest. This is akin to searching for dogs by listening for barks. You won't find all the dogs, and not necessarily the most interesting ones. Just the ones that make a lot of noise.

Similarly, the hunt for alien engineering efforts — if it turns up anything — will only show us the societies that build things easily visible from light-years away. Such constructions may not be typical, nor even of recent vintage. But no matter how singular such artifacts might be, their discovery would answer a long-standing question: Is anyone out there?

For nearly two centuries, we've searched for clever company in our cosmic neighborhood. Once, that search meant examining our solar system for artifacts, until we later switched strategies, hoping to pick up radio signals or other transmissions as the indication of another technological civilization. The latter is an approach that we've followed for a long time now.

Maybe we should revive the strategy of looking for artifacts. Space is vast, and it's conceivable that we'll never meet the aliens themselves. But we might uncover some of their public works.

Seth Shostak *directs the search for extraterrestrials as the senior astronomer and director of the SETI Institute in Mountain View, California.*

to wage war, pollute Earth, and generally hurt ourselves, a theory that resonates is that intelligent life destroys itself or its planet before it can ever establish a permanent space presence. How hopeful do you feel about our species' next hundred years or so?

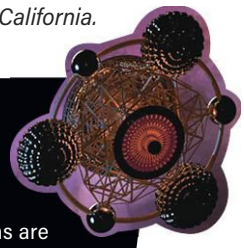
Space is hard. While science-fiction dreams of roaming the stars abound, it might be difficult to put into practice, even given millions of years of opportunity. Maybe interstellar travel never proves economically or technologically practical or justifiable, even for advanced civilizations.

Sorry, didn't see you there. It's possible that alien life is so different from that on Earth that we simply can't recognize it, even when looking right at it. Along similar lines, maybe the life-forms are familiar, but their technology is so different that we don't know how to look or listen for them.

Radio silence. Stephen Hawking advised that humanity should limit our signals to outer space, in case the aliens are hostile. Maybe aliens think the same thing, either in general, or about us in particular.

Among us. Or, of course, they could already be here. While this doesn't usually hold much weight among scientists, many UFO aficionados regard it as a given.

The answers are endless. What's your explanation? —*K.H.*



THE COMET OF THE YEAR

Painters Point near Carmel-by-the-Sea in Monterey County, California, lies beneath the Milky Way and Comet Tsuchinsan-ATLAS in this 18-panel mosaic taken Oct. 22, 2024. Each panel of sky consists of a 30-second exposure taken with an astromodified Nikon Z 6II mirrorless camera at ISO 3200, a zoom lens at 24mm and f/2.8, and a UV/IR cut and Hα bandpass filter. ABHIJIT PATIL

Comet Tsuchinshan-ATLAS treated stargazers in both hemispheres to an impressive display.

BY MARK ZASTROW

COMETS ARE NOTORIOUSLY UNPREDICTABLE. Some of the most spectacular of these icy visitors pop up unexpectedly, careening toward the Sun and bursting out in spectacular fashion with little advance notice. Others are spotted over a year before they make their closest approach, but break apart and fizzle out.

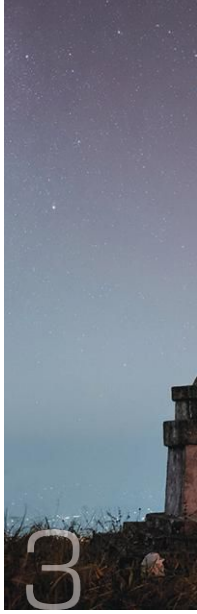
Comet Tsuchinshan-ATLAS was the rare comet that arrived with a year and a half of fanfare and lived up to the hype, serving up naked-eye views for weeks. If it was not a Great Comet, it was at least a very, very good one.

Formally known as C/2023 A3, this ice ball from the outer solar system was first discovered in images taken Jan. 9, 2023, by a telescope operated by Purple Mountain Observatory near Nanjing in China's Jiangsu Province. A month and a half later, it was identified by a telescope in South Africa belonging to the Asteroid Terrestrial-impact Last Alert System (ATLAS). These observations put the object at 670 million miles (1.1 billion kilometers) from the Sun, between the orbits of Jupiter and Saturn.

It wouldn't reach perihelion — its closest point to the Sun — until Sept. 27, 2024. But immediately, the gears of the hype machine began turning.

Initially, it appeared that the best views could wind up being exclusive to the Southern Hemisphere. The comet first became visible in the southern predawn sky, and remained low in the northern sky as it reached perihelion. Soon after, it moved into conjunction with the Sun and was lost in our star's glare. But the best views were yet to come: The comet reemerged as an easy naked-eye evening object around the same time it made its closest approach to Earth on Oct. 12. At its peak, it was recorded as bright as magnitude –4.9, the brightest in the Northern Hemisphere since 1997's Hale Bopp (C/1995 O1). Tsuchinshan-ATLAS also sported a stunning tail stretching up to 15° in photographs, plus a stark anti-tail.

Comets being what they are, there's no telling when one this bright will swing by next. Until then, we have these images to savor.



2 As Comet Tsuchinshan-ATLAS approached, it first graced the Southern Hemisphere with pre-dawn naked-eye views. This shot was taken from Farm Tivoli in Namibia on Sept. 30, 2024, a few days after perihelion. GERALD RHEMANN

3 A trio of Orionid meteors accompany Comet Tsuchinshan-ATLAS in this Oct. 21 composite photo taken from Singalila National Park in West Bengal, India, at an altitude of more than 7,000 feet (2,100 m). The photographer used a Panasonic mirrorless camera and lens at 35mm, capturing the comet with twenty-four 8-second frames at f/4 and ISO 6400. Separate stacks were captured for the starlight and foreground. SOUMYA BANERJEE

4 The comet developed a needlelike anti-tail — a secondary tail that appears to protrude from the comet's nucleus in the opposite direction of the "normal" tails, as pictured here Oct. 17. An anti-tail is a perspective effect created when dust left behind in the comet's orbit appears to point toward the Sun. The imager used a CMOS camera and 135mm lens at f/2.8 to take LRGB exposures totaling 10, 2, 2, and 2 minutes, respectively. ALESSANDRO CARROZZI

5 Comet Tsuchinshan-ATLAS mingles with the stars and spotlights above the Hollywood Hills in this image taken from Griffith Park in Los Angeles on Oct. 12, 2024. The photographer used an iPhone 14 Pro to take a 10-second exposure. NASIR JEEVANJEE

6 The comet's dust and ion tails blend in a combination of orange and blue hues in this shot taken Oct. 14 from Piano Vetore on the southern flank of Mount Etna at an elevation of 5,700 feet (1750 m). The image comprises 25 minutes of exposure with a 2.4-inch refractor and cooled CMOS camera. ALDO ROCCO VITALE

7 The Milky Way serves as a proscenium arch for the zodiacal light and Comet Tsuchinshan-ATLAS in this panorama taken Oct. 19 near Cerro Pachón in the Chilean Andes. The photographer used a Canon 6Da DSLR and a 20mm f/1.4 lens to take twelve 8-second frames at ISO 1600. LUCAS THIBAUD

5

6

WHAT'S IN A NAME?

Comet Tsuchinshan-ATLAS owes its name to two observatories that discovered it independently. The first, Purple Mountain Observatory (PMO), was founded in 1934 and is considered China's first modern astronomical observatory. The name Tsuchinshan — traditionally used for comets discovered by PMO — is an older transliteration of Zijinshan, which is Chinese for "purple mountain." The observatory's historic location is atop a mountain in the heart of Nanjing, a city of nearly 10 million people.

The Minor Planet Center's code for the observatory is Nanking — the historic transliteration of Nanjing. But the bulk of PMO's research is now conducted at several satellite observatories at more remote sites. The telescope that first detected Comet C/2023 A3 is a 1.2-meter Schmidt located in Xuyi County, roughly 30 miles (50 kilometers) northwest of PMO's original site. The Xuyi station reported three detections of the object over a single night, but it was subsequently presumed lost.

The Asteroid Terrestrial-impact Last Alert System (ATLAS) is an network of four telescopes operated by the University of Hawai'i and funded by NASA that scans the entire sky in search of asteroids that could threaten Earth. Two ATLAS scopes are in Hawaii, one is in Chile, and one is in South Africa. The latter — a 0.5-meter Schmidt at the South African Astronomical Observatory in Sutherland — is the one that independently detected Comet C/2023 A3, on Feb. 22, 2023. Subsequent analysis revealed that it was the same object discovered by PMO. *—M.Z.*

TOP: A Perseid meteor streaks behind the dome of Purple Mountain Observatory's Xuyi Station, the first facility to detect Comet C/2023 A3. HAO LIU

BOTTOM LEFT: The ATLAS telescope in Sutherland, South Africa, is pictured here under construction in 2021. WILLIE KOORTS/SAAO

BOTTOM RIGHT: The Moon rises behind Purple Mountain Observatory's historic facility in Nanjing. The photographer captured the scene with a Nikon DSLR and zoom lens at 500mm with an exposure of 1/50 second, f/5.6, and ISO 1000. HAO LIU

8

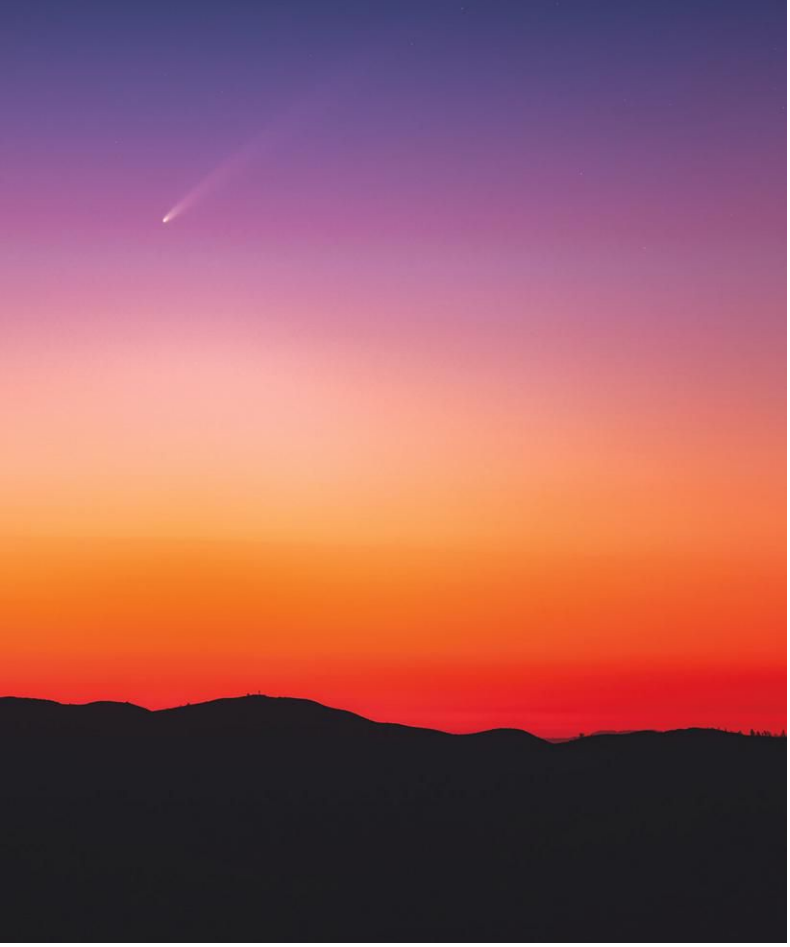
8 Comet Tsuchinshan-ATLAS appears above the ridgeline of the Diablo Range in this Sept. 28 shot taken from Lick Observatory, California. The photographer captured the comet in a tracked 10-second exposure at ISO 100 with an astromodified Nikon mirrorless camera and a 200mm zoom lens at f/2.8. ABHIJIT PATIL

9 The comet shares the frame with the Milky Way and satellite streaks over the mountains outside Salt Lake City. This image is a 60-second exposure taken with a Canon DSLR and 14mm lens at f/2.5 and ISO 1600. MARTIN RATCLIFFE

10 A sinuous ion tail and brilliant dust tail are on display in this shot taken Sept. 30, three days after reaching perihelion. This image was captured with a combination of DSLR and astronomical cameras in LRGB filters. GERALD RHEMANN/MICHAEL JÄGER/DENNIS MÖLLER

11 The comet's long tail appears in this 30-second shot taken from Caçapava, São Paulo, Brazil. The photographer used a Nikon DSLR and 50mm lens at f/2.2 and ISO 250. Orbits of long-period comets like Tsuchinshan-ATLAS cannot be predicted precisely, but on its current course, it won't return for around 80,000 years. JEAN CURSINO

Mark Zastrow *is a senior editor of* Astronomy.



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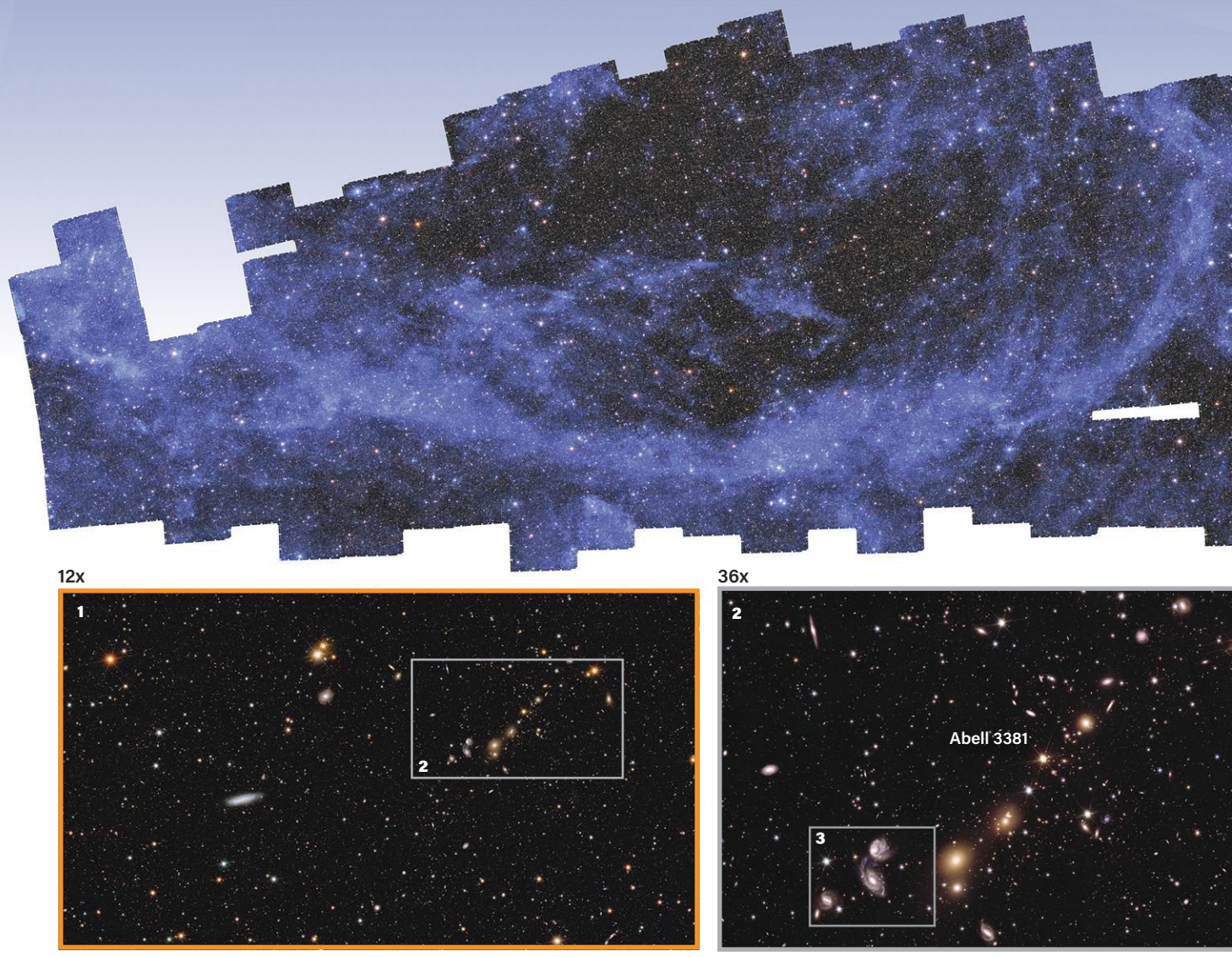


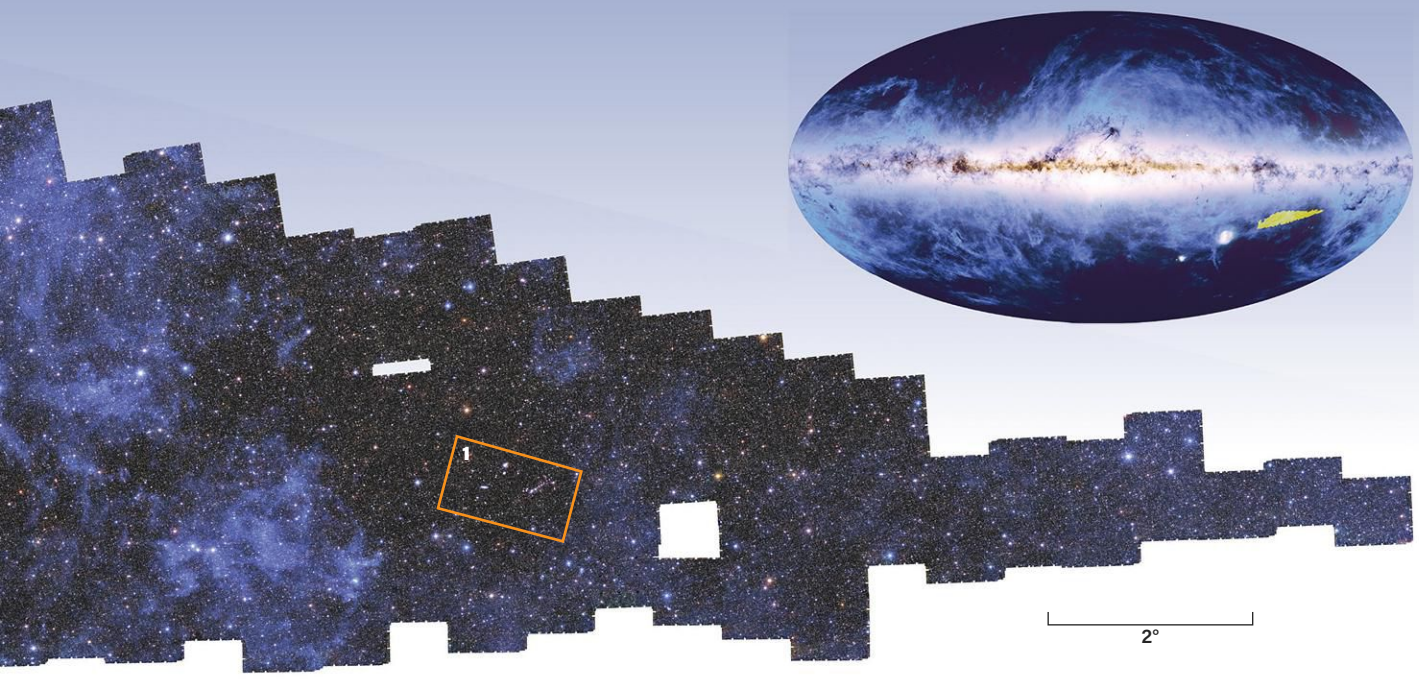
Euclid captures

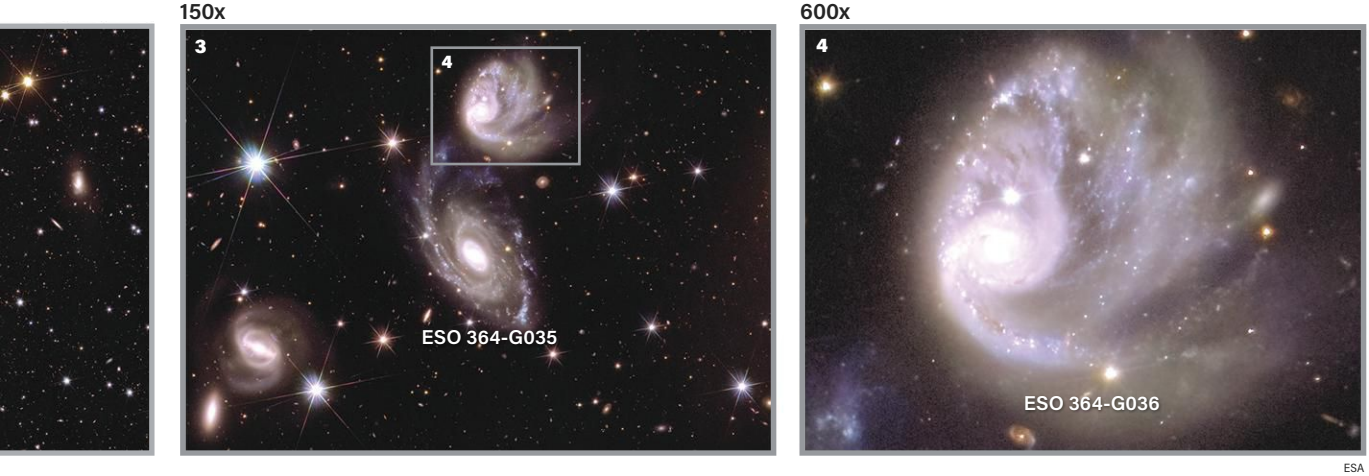
Europe's new space telescope will create a 3D map of the cosmos to explore the effects of dark energy. BY KOREY HAYNES

THE EUCLID SPACE OBSERVATORY launched July 1, 2023, from Cape Canaveral, Florida. Researchers tasked it with creating a 3D map of more than a third of the sky and surveying billions of galaxies up to 10 billion light-years away. In October of last year, scientists revealed the first page in its cosmic atlas, a mosaic comprising 208 gigapixels of data revealing billions of galaxies in awesome detail.

A project of the European Space Agency, Euclid scans the cosmos in visible and near-infrared light with a telescope aperture of 1.2 meters. Instruments include an infrared spectrometer, which allows it to measure the composition and motions of targets in detail and reveal galaxies at a great distance, when the universe was in its childhood.

Euclid is meant to answer major cosmological questions about the makeup and evolution of the universe, but its huge and detailed view will also yield data on individual galaxies, star populations, supernovae, exoplanets, the dimmest brown dwarfs, and many examples of gravitational lensing, when distant objects are magnified by closer objects in line with them bending their light.





ESA

billions of galaxies

The mosaic released last October combines 260 observations containing some 14 billion galaxies, as well as tens of millions of individual stars closer to home.

In the series of crops shown above, the galaxy cluster Abell 3381 emerges from the depths of space with each zoom. It first appears as a tiny string of glowing beads on the right side at a magnification of 3x, and eventually fills the image at 36x. The cluster lies some 678 million light-years away.

At higher magnifications, a pair of interacting galaxies are highlighted, 420 million light-years from Earth. ESO 364-G035 and G036 are clawing at each other's outer layers, distorting the clearly resolved spiral arms.

The final image (600x), centered on G036, represents just 0.0003 percent of the original mosaic, which is itself only 1 percent of Euclid's full survey.

Only the beginning

When Euclid's six-year survey is complete, it will encompass more than a third of the celestial sphere, steering clear of the Milky Way's bright central regions and focusing on the darker parts of our sky. Euclid's final atlas will also contain deep-field regions similar to Hubble's famous images of the darkest, farthest, oldest corners of space.

The public can enjoy another 53 square degrees of Euclid's view of the sky released in March, including the mission's first deep-field imagery.

In the meantime, Euclid will continue its quiet contemplation of the cosmos' deepest mysteries.

Korey Haynes *is a science writer who enjoys the universe's colder side from her home in Minnesota.*

SKY THIS MONTH

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.

BY MARTIN RATCLIFFE AND ALISTER LING

Mars stands near the Beehive Cluster (M44) at upper left in this 2010 astrophoto. The Red Planet again visits the Beehive this month. ALAN DYER

MAY 2025

The Red Planet pokes the Beehive

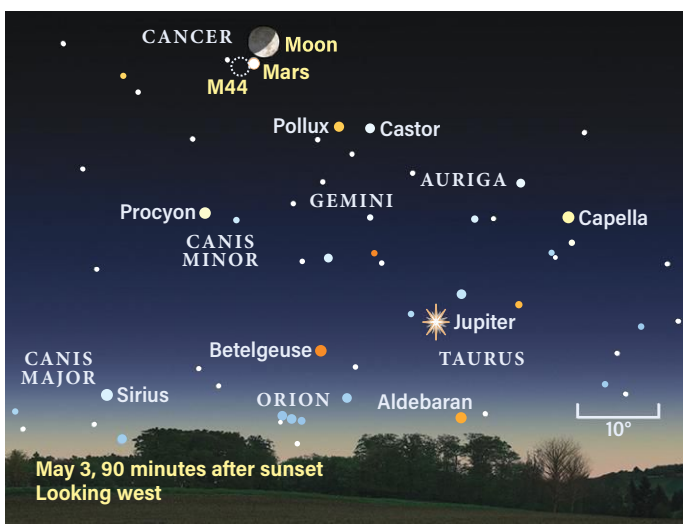
Jupiter and Mars are on display during May evenings. It's your last chance to grab a good view of Jupiter before it drops out of sight for midsummer. A gathering of planets in the morning sky offers some nice opportunities, and in the first week of May they're joined by meteors from the annual Eta Aquariid shower.

Let's begin our tour with Jupiter, continuing its long goodbye as its elongation from the Sun diminishes from 40° to 18°. It sets just after 11 P.M. local daylight time on May 1st and around 9:30 P.M., or about an hour after sunset, on May 31. Your finest views occur in the first few days of the month, when the planet spans 34" and remains above 20° altitude an hour after sunset.

Jupiter shines at magnitude –2.0 in early May and lies in Taurus the Bull. It appears in the western sky along with Orion, Gemini, and Auriga. On May 18, it stands 2° due north of Zeta (ζ) Tauri, with the faint Crab nebula (M1) 1.3° southwest of the planet, although twilight will render the nebula invisible.

Jupiter is magnificent when viewed through a telescope in twilight. This is because the glare of the planet is diminished. Delicate atmospheric details — such as the dark equatorial belts and more

Three for one



In early May, Mars visits the Beehive Cluster (M44). On the 3rd, the Moon joins in as well. One night later, Mars skims 40' north of the Beehive's center.

ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

MARS passes 40' north of the center of **M44** on May 4.

temperate-latitude dark belts, bright zones, and plumes — span the disk. The apparent diameter of Jupiter shrinks to 32" by the end of the month.

By May 7th, the planet falls below 20° an hour after sunset and becomes more difficult to observe, particularly if you have obstructions to the west. The narrowing observing window nonetheless provides some interesting events involving the Galilean moons. Io performs a transit with its shadow on May 4. Io reaches Jupiter's eastern limb at 9:06 P.M. EDT, its

— *Continued on page 34*

RISING MOON | I lava you

THE MOON'S FROZEN FACE records the scars of its dual past life, volcanic and bombastic. The prominent impact crater Copernicus is the gateway to this short lunar trip. When it lies on the line separating light from dark, the terminator, its high walls stand out above the surrounding plain. Sunrise over this beautifully complex region occurs on the 6th.

The lit side of Copernicus has a textured surface that looks like the aftermath of a small rock landing in a mud puddle: Apart from a draping of splattered material, numerous secondary pits formed when blast remnants fell shortly after the main impact.

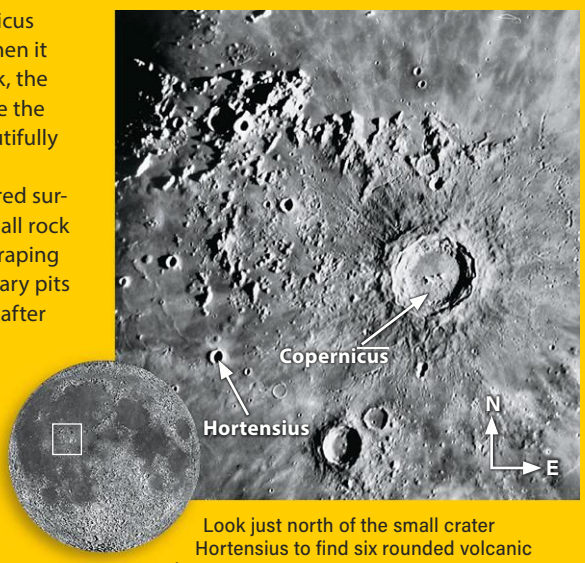
By the 7th, the Sun illuminates the western side, where a bunch of jumbled peaks stick out above the lava-flooded surface. Along the terminator that has shifted to the lunar west is the smaller crater Hortensius. Look closely to the north to see a cluster of six volcanic domes. Each little bump sports its own shadow, but only with a very low Sun angle are these domes noticeable. These light-dark doublets are much softer than the harsher lighting from crater rim to floor.

In his book *The Modern Moon*, Charles Wood writes that these domes are about 4 miles wide and 1,000 feet or so high. If the night is superb, a 6- to 10-inch scope might reveal a summit pit. Wood notes that despite advances in lunar geology, we don't know whether they were formed by uplift from below or gradually built up by a longer-term quiet eruption.

Find another large dome just west of Milichius. You could literally spend hours watching the fantastic play of light and dark in the area of Copernicus.

Remember also to look for Mare Orientale at and just after Full Moon. (See last month's column for more details.)

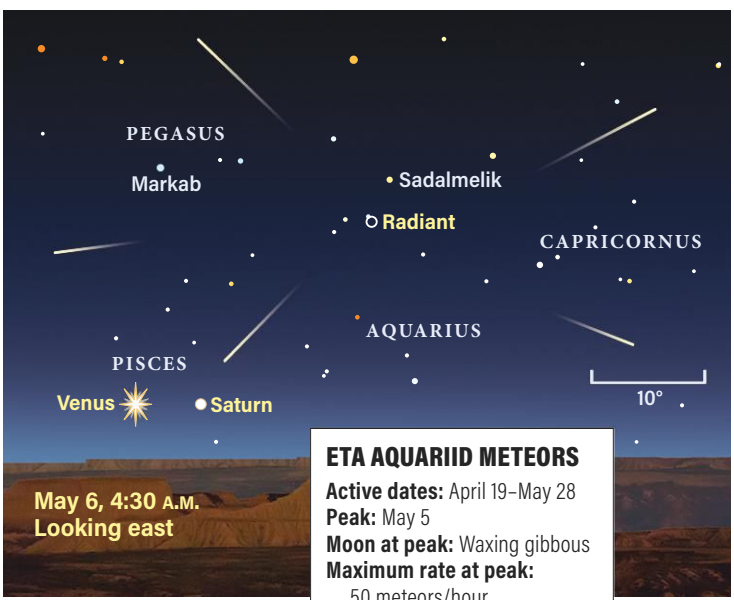
Hortensius dome field



Look just north of the small crater Hortensius to find six rounded volcanic domes. *CONSOLIDATED LUNAR ATLAS*/UA/LPL. INSET: NASA/GSFC/ASU

METEOR WATCH | Catch a long train

Eta Aquariid meteor shower



ETA AQUARIID METEORS
Active dates: April 19–May 28
Peak: May 5
Moon at peak: Waxing gibbous
Maximum rate at peak: 50 meteors/hour

THE WARMTH OF A SPRING EVENING is welcome across the Northern Hemisphere. If you venture out at night, you might capture a fleeting view of dust particles ejected from Halley's Comet on its many orbits around the Sun. They are visible as swift meteors from the annual Eta Aquariid meteor shower, one of two associated with Halley's orbit (the other is the October Orionids).

The shower is active from April 19 to May 28, and peaks the evening of May 5. The radiant lies near Zeta (ζ) Aquarii, which rises at 2:30 A.M. local daylight time across the U.S., just before the gibbous Moon sets in the west. The radiant reaches an altitude of 20° two hours later, just as the first signs of twilight appear. This low altitude attenuates the zenithal hourly rate of 50 meteors per hour down to an expected observable rate of 10 per hour. These swift meteors travel at roughly 40 miles per second, many with persistent trains, making it worth spending a couple of hours to see perhaps a dozen good meteors, just in time for morning coffee.

The Eta Aquariids peak late on May 5; the radiant rises early on May 6. Neptune, not visible to the naked eye, is not shown.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

midnight May 1
11 P.M. May 15
10 P.M. May 31

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

MAY 2025

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

2 Asteroid Vesta is at opposition, 2 A.M. EDT

3 The Moon passes 2° north of Mars, 7 P.M. EDT

Venus passes 2° north of Neptune, 11 P.M. EDT

4 First Quarter Moon occurs at 9:52 A.M. EDT

5 Eta Aquariid meteor shower peaks

6 Pluto is stationary, 2 A.M. EDT

9 Asteroid Metis is at opposition, 2 A.M. EDT

10 The Moon passes 0.4° south of Spica, 4 A.M. EDT

The Moon is at apogee (252,428 miles from Earth), 8:47 P.M. EDT

12 Full Moon occurs at 12:56 P.M. EDT

14 The Moon passes 0.3° south of Antares, 1 A.M. EDT

Asteroid Juno is at opposition, 2 P.M. EDT

17 Uranus is in conjunction with the Sun, 8 P.M. EDT

18 The Moon passes 0.4° south of Pluto, 8 A.M. EDT

20 Last Quarter Moon occurs at 7:59 A.M. EDT

22 The Moon passes 3° north of Saturn, 2 P.M. EDT

The Moon passes 2° north of Neptune, 5 P.M. EDT

23 The Moon passes 4° north of Venus, 8 P.M. EDT

25 The Moon is at perigee (223,086 miles from Earth), 9:34 P.M. EDT

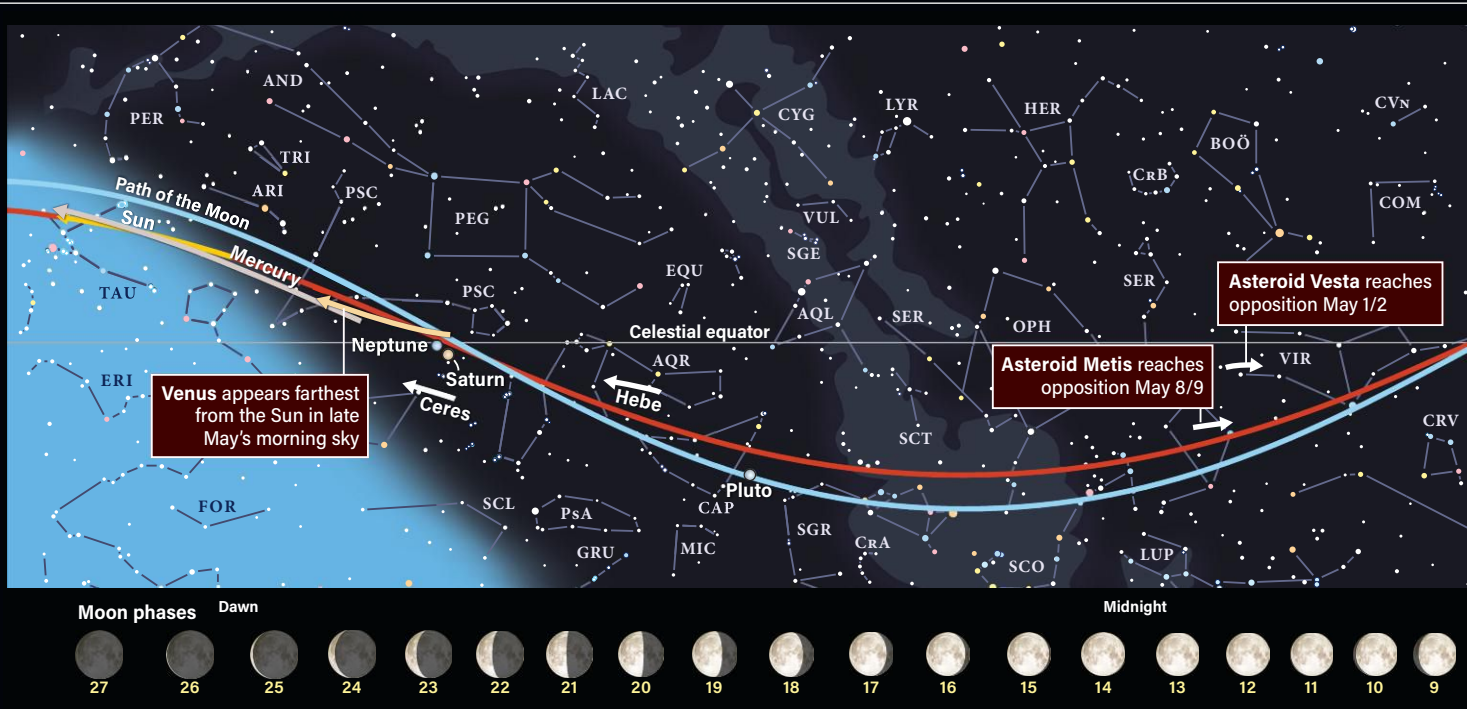
26 New Moon occurs at 11:02 P.M. EDT

28 The Moon passes 5° north of Jupiter, 9 A.M. EDT

29 Mercury is in superior conjunction, midnight EDT

31 Venus is at greatest western elongation (46°), midnight EDT

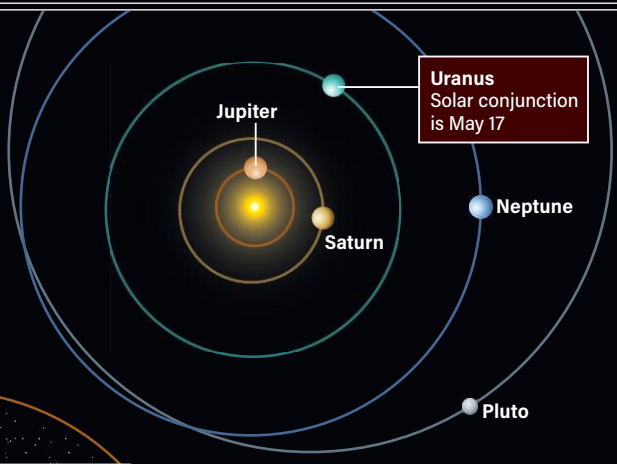
PATHS OF THE PLANETS

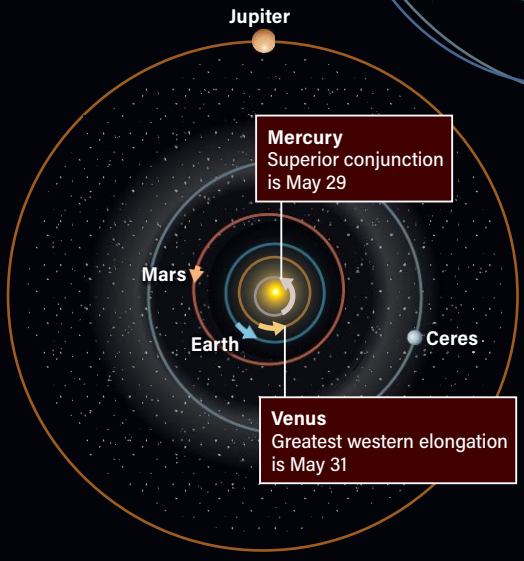


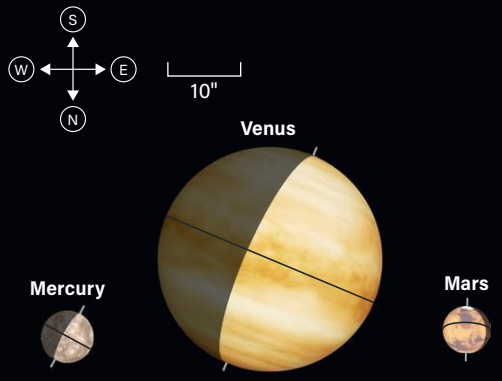
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

THE PLANETS IN THEIR ORBITS

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.



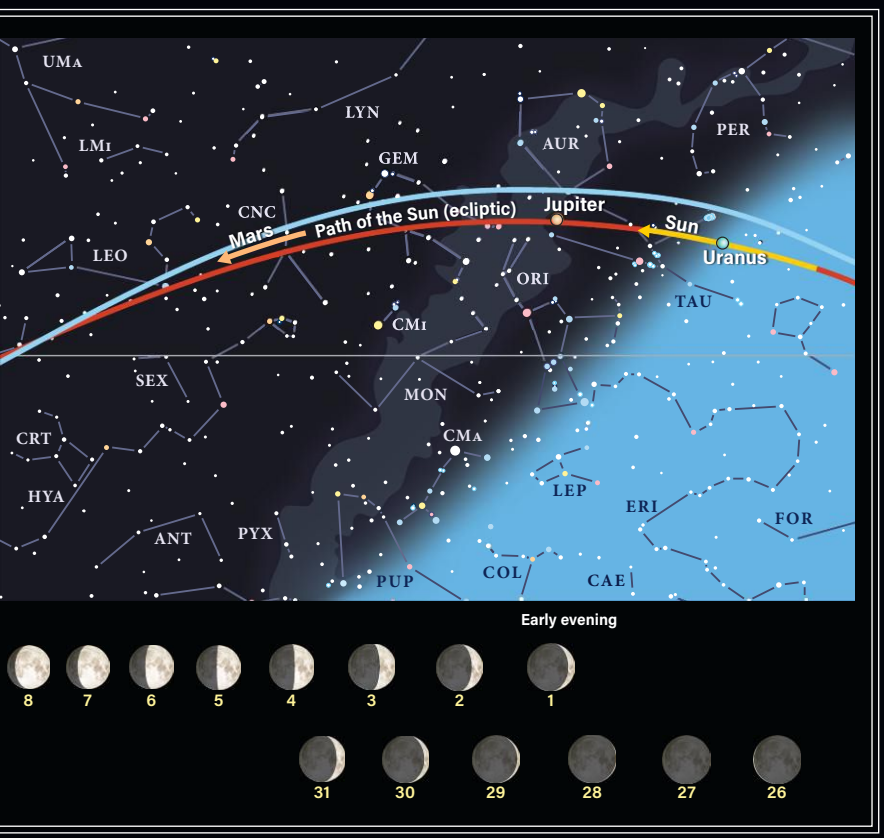




PLANETS	MERCURY	VENUS
Date	May 1	May 15
Magnitude	0.1	–4.6
Angular size	6.8"	29.6"
Illumination	59%	39%
Distance (AU) from Earth	0.993	0.563
Distance (AU) from Sun	0.442	0.727
Right ascension (2000.0)	1h00.3m	0h36.1m
Declination (2000.0)	3°19'	3°01'

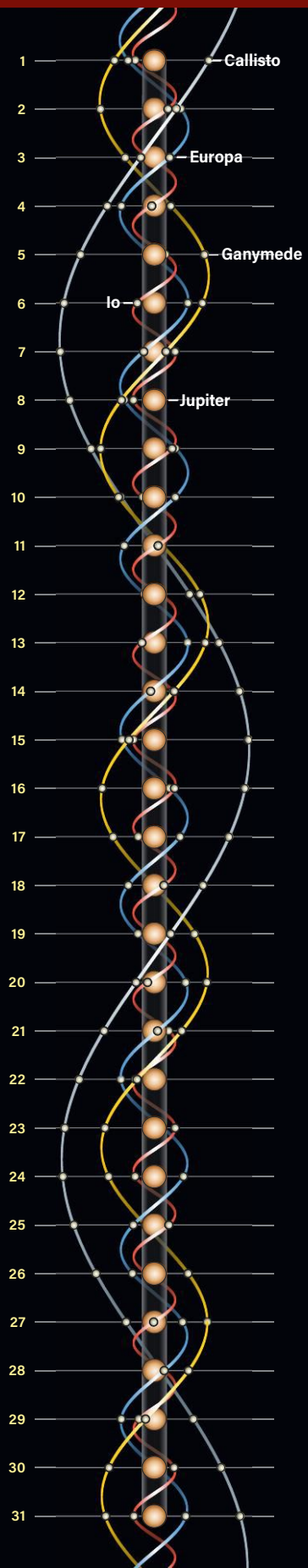
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

MAY 2025



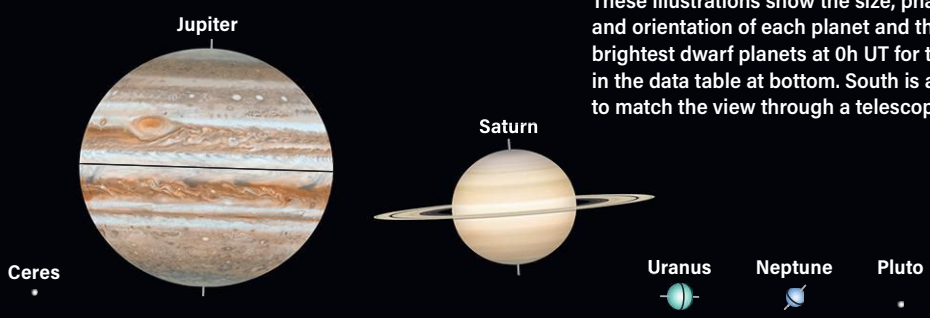
JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.



THE PLANETS IN THE SKY

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
May 15	May 15	May 15	May 15	May 15	May 15	May 15
1.1	9.3	–1.9	1.1	5.8	7.8	15.3
6.0"	0.4"	33.0"	16.4"	3.4"	2.2"	0.1"
90%	98%	100%	100%	100%	100%	100%
1.549	3.436	5.980	10.129	20.540	30.489	34.894
1.662	2.982	5.128	9.590	19.530	29.891	35.263
8h59.6m	0h11.2m	5h33.6m	23h58.9m	3h38.1m	0h06.2m	20h26.6m
18°52'	–8°42'	23°05'	–2°21'	19°14'	–0°44'	–22°52'

 — Continued from page 29

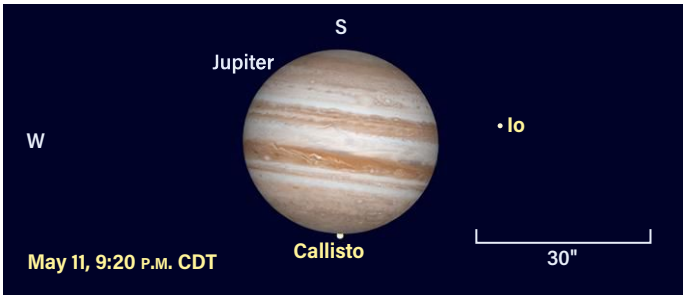
WHEN TO VIEW THE PLANETS

EVENING SKY
Mars (west)
Jupiter (west)

MIDNIGHT
Mars (west)

MORNING SKY
Mercury (east)
Venus (east)
Saturn (east)
Neptune (east)

Skimming the top



Callisto just skims the northern edge of Jupiter on May 11, not long before Io begins a transit and Ganymede, hidden in the planet's shadow, reappears to the northeast. Europa lies to the west, beyond this field of view.

shadow following at 9:54 P.M. EDT. From the Central time zone west, the transit is already underway in twilight.

The following evening, May 5, watch Europa disappear behind the western limb of Jupiter at 10 P.M. CDT. This event is best viewed in the western U.S. — Jupiter is getting very low (less than 10° high) for Midwest observers and has already set for those along the Eastern Seaboard.

The orbital plane of the Galilean moons is tilted such that Callisto misses any occultations or transits, but this month Callisto slides very close to the northern pole of Jupiter. Watch this unusual event on the evening of May 11. The closest point, where the edge of Callisto is predicted to graze the northern edge of Jupiter, occurs around 9:20 P.M. CDT. Watch all evening as the fascinating encounter plays out. Also watch Io begin a transit at 9:07 P.M. MDT (Jupiter is now very low in the Central time zone), just minutes before Ganymede reappears off the planet's northeastern limb from within Jupiter's shadow.

Europa performs a nice transit followed by its shadow on May 14, beginning at 8:12 P.M. EDT. The shadow appears as Europa reaches the central meridian of Jupiter, at 9:30 P.M. EDT. The western half of the country sees Europa exit the disk at 8:52 P.M. MDT, while its shadow is near the middle of the disk. Galilean satellite events in late May become difficult to observe as Jupiter dips below most observers' tree line in the late evening.

Mars provides a lovely addition to Cancer the Crab as May opens, shining at 1st magnitude. It stands within 2° of M44, the Beehive star cluster, and the scene is best viewed in binoculars.

Two days later, on the 3rd, a waxing crescent Moon joins Mars. Our satellite passes within 2° of the planet, which is now skirting the outer limits of M44. The next evening, Mars is 40' due north of the center of the Beehive, a stunning pairing in binoculars or low-power telescope eyepiece.

During the rest of May, Mars continues across eastern Cancer and moves into Leo on the 25th. By the 31st, Mars stands 9° northwest of Regulus, Leo's brightest star. It remains visible until roughly 1 A.M. local daylight time. Mars now appears 6" in diameter, making it very small; it is difficult to view surface features with a telescope.

Planetary action moves to the morning, with the appearance of Venus and Saturn climbing high in the predawn sky. **Venus** is obvious and shines at magnitude –4.7. It's located south of the Great Square of Pegasus, among the stars of western Pisces.

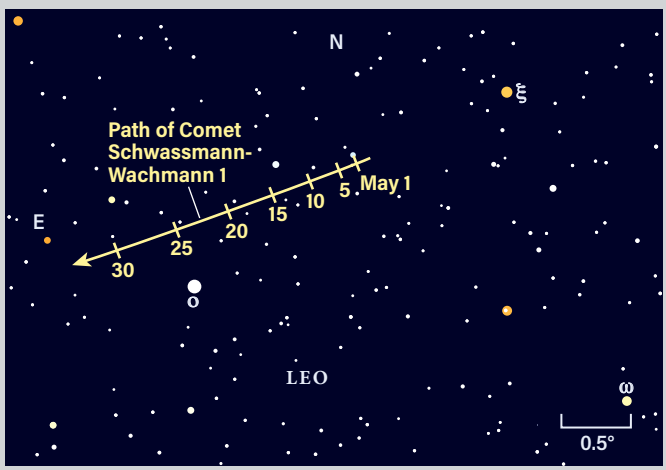
Saturn stands 4° south of Venus on May 1, a planetary pairing that provides interesting contrast when each is viewed through a telescope. Both planets are above the horizon by 5 A.M.

COMET SEARCH | Digging deep in the dark

M95, M96, AND M105 in the belly of Leo are targets in the Messier marathon. You've primed your eyes and mind on them, now turn to the nearby quirky Comet 29P/Schwassmann-Wachmann. Astronomers can't predict when it will pop up to 11th magnitude, which it does every year, sometimes twice. You will need an 8-inch scope well away from city lights.

The key to seeing small, faint objects is to make them bigger. Before the information even travels down the optic nerve, your retina bins neighboring cells that "agree" to increase the signal to noise. Sit down to avoid straining, put 100x on M105, then 150x, and even 200x; use a hood, but exhale to the side. Note which magnification best shows its magnitude 11.8 companion, NGC 3389. That's our comet analogue.

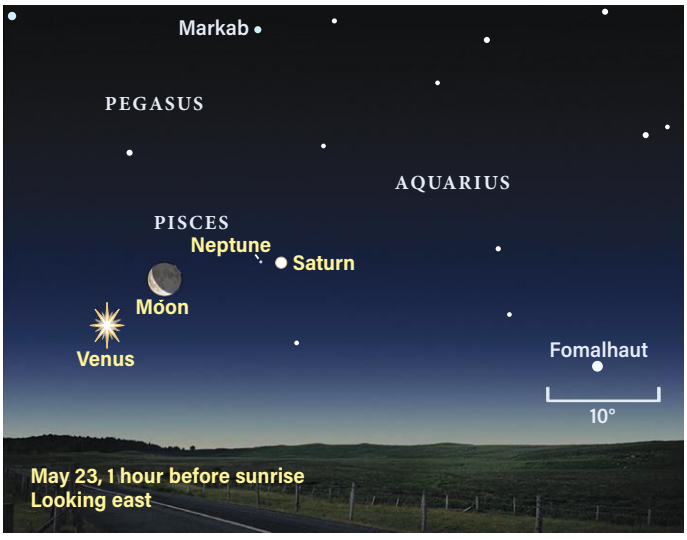
Comet 29P/Schwassmann-Wachmann



Comet 29P/Schwassmann-Wachmann, also called Schwassmann-Wachmann 1, is traversing the region near Omicron Leo, not far southwest of Regulus. Too faint? A week later it might be in outburst.

Over at luminary Regulus, ease to the lower right to magnitude 3.5 Omicron (o) Leonis, then shift north. Use our chart to home in on Schwassmann-Wachmann's location, and put in your chosen eyepiece. If it's not immediately visible, dark adapt a bit more and tap the tube to activate the motion sensitivity of your averted vision. You've got it when the ghost shows up again in the same spot!

Moon in the middle



The Moon hangs between bright Venus and Saturn in the early-morning sky in late May. Neptune, nearby, requires binoculars or a telescope to spot.

local daylight time. Saturn shines at magnitude 1.2 and its rings are close to edge-on. Venus exhibits a 30-percent-lit crescent spanning 36".

Neptune also lies in this direction, far beyond both Venus and Saturn, and is difficult to see in early May, when both Venus and Saturn lie about 3° from the more distant world. By the end of May, Neptune stands 1.6° northeast of Saturn and can be spotted with a pair of binoculars, glowing at magnitude 7.8.

Viewing Saturn's rings is difficult with the low altitude and approaching twilight, but it's worth a try in the first few days of May because we are glimpsing the backlit side of the rings. If seeing conditions allow, you might see the gossamer-thin black line of the rings' shadow on Saturn's 16"-wide disk.

After May 6 — the date of Saturn's equinox, when the Sun is exactly edge-on to the rings — the shadow essentially disappears. On the next morning, May 7, the southern face of the rings, tilted by 2° to our line of sight, becomes sunlit for the first time in more than 15 years. Observing these fascinating changes in the rings is challenging, but it's worth the effort if you have a large telescope and clear eastern horizon.

Saturn continues to climb higher in the morning sky and meets with a waning crescent Moon on May 22. By May 31, it's rising before 3 A.M. local daylight time and stands 15° high in the eastern sky at the onset of morning twilight.

Venus extends its elongation from the Sun during the month and is carried eastward against the background stars of Pisces, away from Saturn. A waning crescent Moon stands within 7° of Venus on the 23rd.

A telescope reveals the disk of Venus diminishing to 24" during the month. At the same time, its phase grows to 49 percent lit by the last day of the month, when it reaches greatest elongation from the Sun. Venus is best observed in twilight to avoid the dazzling brilliance of the planet when viewed in darkness.

Mercury appears very low in the eastern morning sky in early May, shining at magnitude 0.1. It rises 50 minutes before the Sun on May 1, and only 40 minutes ahead of the Sun by May 12, when the planet has brightened to magnitude –0.5. Its southerly declination makes it a tougher target for Northern Hemisphere observers, whereas those in the Southern Hemisphere have a great view.

If you can catch this elusive planet in a telescope, you'll spot a gibbous disk growing from 60 percent lit on the 1st to 77 percent lit on the 12th. Mercury quickly dips out of view after the second week of May. Orbiting on the other side of the solar system from Earth, Mercury reaches superior conjunction with the Sun on May 29.

Uranus is out of view and is in conjunction with the Sun May 17.

Martin Ratcliffe *is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City.* **Alister Ling**, *who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

LOCATING ASTEROIDS
Back on Easy Street

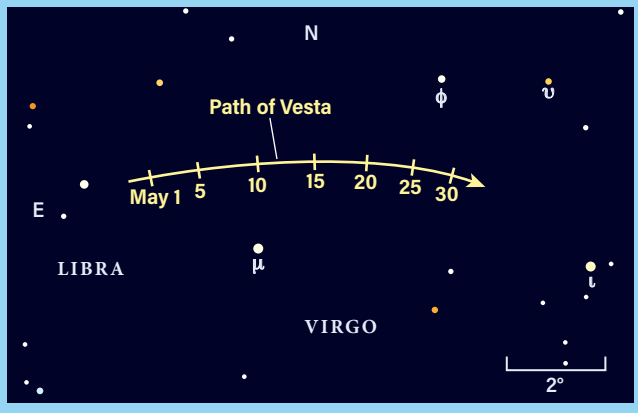
FROM A CITY BALCONY OR PARK, you can spy a main-belt asteroid through binoculars with just a couple of minutes of dark adaptation. Point to a spot halfway between brilliant orange Arcturus and blue-white Spica, and drop two to three fields down. It's even easier to get to than the directions sound.

Overshoot to hit the lovely wide double star Zubenelgenubi. Evening observers can tilt the finder chart to the left to match the orientation in the sky. Lock in on the gently curving chain of equally spaced stars as you sweep field to field. The only "star" anywhere near the upper two, Mu (μ) and Phi (ϕ) Virginis, is 4 Vesta.

The fourth asteroid to be discovered, Vesta is at peak brightness of magnitude 5.7 on the 2nd, when it lies in opposition to the Sun. When the Moon reaches its opposition — Full phase — it passes so far below that you should be able to follow Vesta the entire month.

See it with unaided eyes too! From a dark site in the last third of May, pick it out during a break from telescopic viewing when it is higher in the sky, above the horizon haze.

Few rivals



Vesta is easy to find this month, skimming through a region with few stars rivaling its brightness.

ECLIPSE SUCCESS

ON EASTER ISLAND

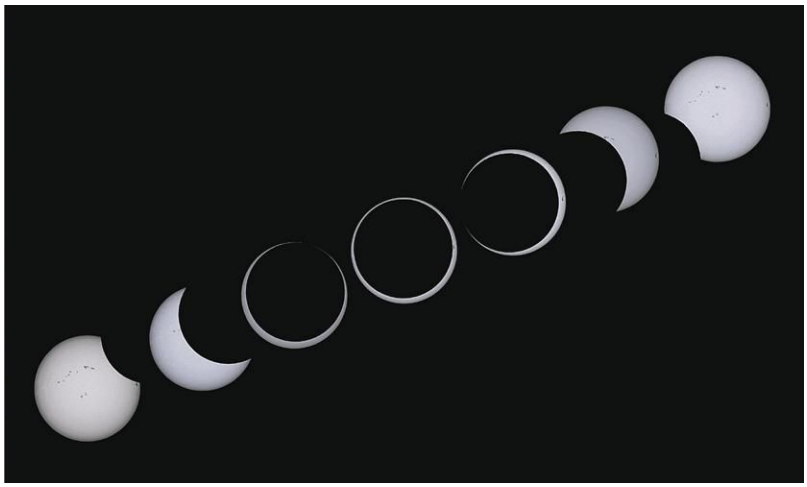
This spectacular locale presented a stunning dark sky, a famous comet, and the main event — an annular eclipse. BY DAVID J. EICHER

***ASTRONOMY*'S EDITOR HERE.** Last October, I ventured out on a weeklong trip to a very special place. I departed from Tucson, Arizona, and traveled to Santiago, Chile, where I met about 20 enthusiastic people who were charged up to see the annular eclipse on Oct. 2.

Before heading for the considerably long flight to Easter Island, our group enjoyed some sights and sounds of Chile. In the city of Santiago, we took a city tour and walked around the Plaza de Armas, the city's main square, soaking in the extraordinary history and architecture of the region. We explored the Metropolitan Cathedral, and the city's northeastern sector, loaded with fancy restaurants and shops, and the picturesque area of San Cristobal Hill. And then, we made a 5½-hour flight westward from the Chilean coast to one of the most remote and storied places on the planet, Easter Island.

RIGHT: The annular eclipse is given a geometric design by the photographer's Canon EOS R5 aperture blades. After third contact, the Moon was exiting the Sun's disk. FELIPE MENZELLA

FAR RIGHT: The Moai statues are one of the reasons why Easter Island is known globally. These megaliths are carved from basalt and date back from 1200 C.E. to 1500 C.E. DAVID J. EICHER



LEFT TO RIGHT: Editor-in-chief Dave Eicher poses in front of Easter Island's ancient relics, a long row of Moai statues. DAVID J. EICHER

A montage of the annular solar eclipse's progression, captured on Easter Island, reveals the crisp lines of each stage — especially the ring of fire. ALLEN HWANG

Members of *Astronomy* magazine's eclipse-chasing group observe the partial phases of October's annular eclipse before the ring of fire appears. CENGIZ ARAS

On average, Easter Island megaliths are around 13 feet (4 m) tall and weigh 13.78 tons. The smallest standing Moai statue is only 3.76 feet (1.13 m), whereas the largest known monolith is 72 feet (22 m) tall and weighs about 155 tons! DAVID J. EICHER

Let the gazing begin

Oct. 2 presented a rare astronomical triple-play day that comes along only rarely. Our intrepid group, led by Cengiz Aras, CEO of our tour partner Eclipse Traveler, set off at 6 A.M. to a remote observing site on this small island. Arriving half an hour later, we set up opposite a long row of the famous Moai statues, constructed between approximately 1200 C.E. and 1500 C.E., and readied ourselves for sunrise.

The first spectacle of the day came in while viewing a pristine, dark morning sky. Brilliant planets and wintertime constellations were high overhead — we admired a dazzling Jupiter, Mars, and Saturn, along with the glories of Orion, Taurus, Canis Major, and the rest of the gang. Crux stood above the horizon, as well as the other deep-sky wonders of Carina.

It always amazes me to observe the Orion Nebula and then look over, in the same sky, to see the Carina Nebula, dwarfing Orion in size and brightness. We also had the Magellanic Clouds, hazy and well defined — as if bright patches of the Milky Way were chopped off and relocated — and the great globular star cluster 47 Tucanae beside the Small Magellanic Cloud. We were enchanted by the numerous splendors of the southern sky.

And the glories kept coming. As dawn began to brighten, we saw the brilliant comet C/2023 A3 Tsuchinshan-ATLAS shining brightly at around 2nd magnitude. It rose from the eastern horizon, among the row of Moai statues. It was a bewildering astronomical treat that seemed like something out of a film, so dazzling.

A burning ring of fire

After the Sun rose, we then returned to our luxury hotel, where I prepared for a lecture I later delivered during the eclipse's initial stages. A few clouds hopped around the sky as we set off for the eclipse locality, but nothing too alarming. And sure enough, as 12:23 P.M. local time approached, we had a clear sky with a few small cumulus passing above.

Once first contact began, we could officially start enjoying the delights of an annular eclipse — one in which the Moon was relatively distant and made a somewhat small black disk creeping across the Sun. The precision of the timing never fails to impress observers, and our hats were once again off to Johannes Kepler.

An hour and a half later, we witnessed the start of annularity, in which the Moon's disk obscured 87 percent of the Sun, leaving a "ring of fire" around it. Our Easter Island annular eclipse lasted for 5 minutes 48 seconds — a long eclipse — before

third contact began to restore the Sun, slowly. At just before nearly 4 P.M. local time, the eclipse ended. We could count an incredible trio of astronomical treasures: the dark southern sky, the comet, and a great annular eclipse.

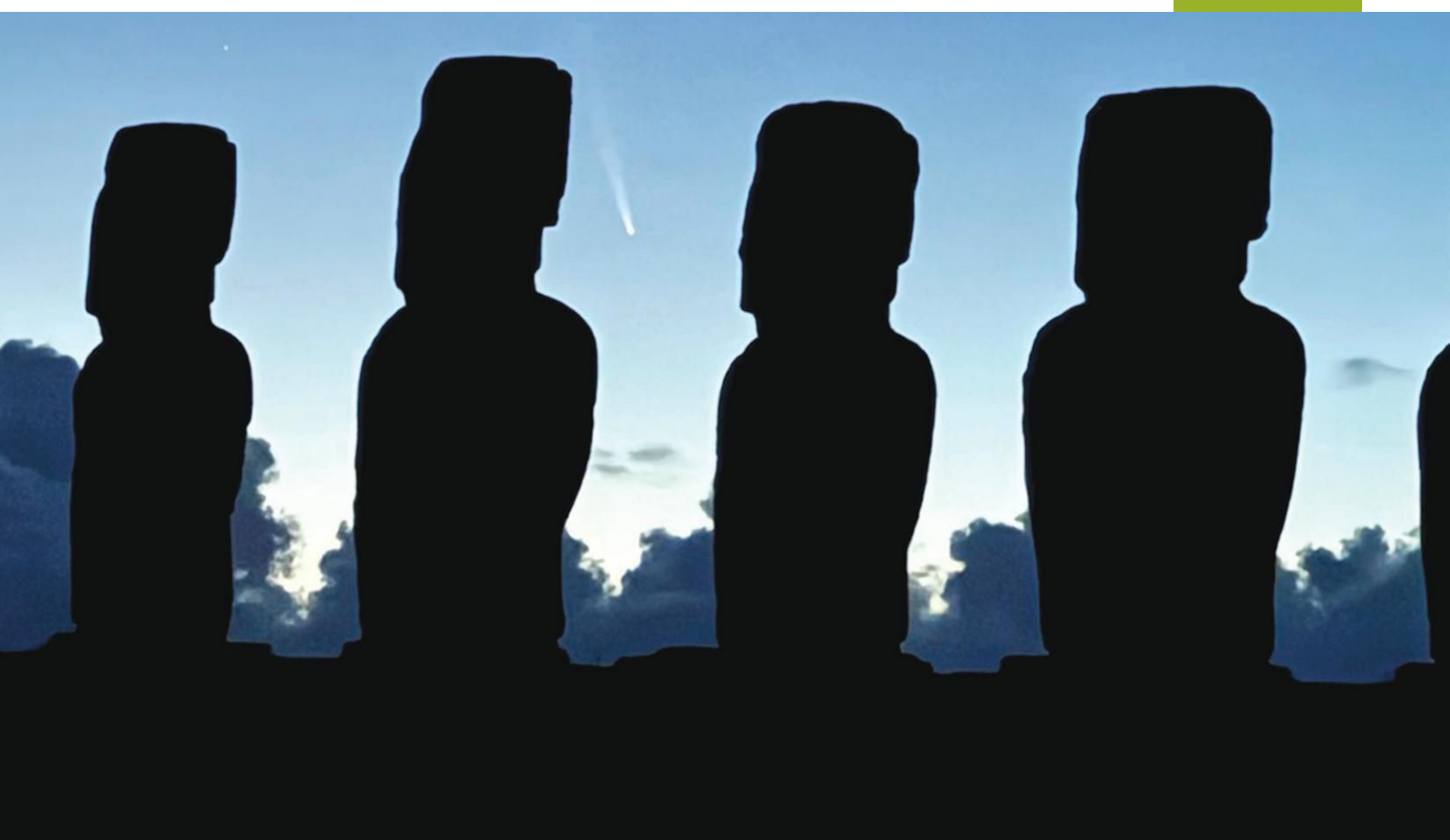
On the other side of the eclipse, we continued to explore Easter Island for another day and a half. Seeing the many dozens of Moai was amazing, along with other treats of the island. Then we headed back to Santiago. Another eclipse under our belt, another bright comet witnessed, and another session under the deep southern sky — which my old pal, the Dutch-American astronomer Bart Bok, used to say "has all the good stuff in it."

Later in the journey, we enjoyed sightseeing in Valparaiso, and extensively explored the La Sebastiana Museum and its stunning art collections. It is always an enriching experience, absorbing such striking and very different areas and experiences than one gets back at home.

What a whirlwind eclipse tour it was. I hope you saw the eclipse too, or at least some of the magnificent images recorded of this phenomenon!

David J. Eicher *is editor-in-chief of* Astronomy *magazine, author of 26 books on science and history, and a member of the board of the Starmus Festival and of Lowell Observatory.*

BELOW: The dazzling comet C/2023 A3 Tsuchinshan-ATLAS glowed brightly at about 2nd magnitude as it rose in the early morning sky behind ancient Moai statues on Easter Island. ANTHONY ALLEN ANDERSON



10 WOMEN who changed astronomy

Often bucking tradition, these women sought knowledge of the universe and reimagined the way we view the cosmos.

BY SAMANTHA HILL

Women have long contributed meaningful scientific discoveries to the field of astronomy; however, men have primarily dominated the vocation. As of 2019, women earn about 40 percent of the Ph.D.s granted in the field of astronomy, but that has not always been the case.

And there are many cases of women working in astronomy only to have their findings overshadowed or derided in some capacity. Until relatively recently, women typically had to be related or married to a prominent astronomer, take on remedial roles, do research in secret, or even forgo access to a public bathroom, all in the pursuit of knowledge of the stars.

To highlight their accomplishments despite the challenges they faced, I have researched and devised a list of women that I found to be incredibly influential to the field of astronomy. This is by no means an exhaustive account — not even close. But the biographies here are a celebration of some of the most profound developments made by women as well as discoveries that changed our understanding of the universe.

A group of women on the staff of the Harvard College Observatory were known as the Harvard Computers. HARVARD UNIVERSITY ARCHIVES

Caroline Herschel
1750–1848

One of the first women to be a professional astronomer, Caroline Herschel discovered eight comets, 500 stars, and 2,500 nebulae in her long life.

Moving from her home in Hanover, Germany, to England in her early 20s, Herschel and her brother William pursued a career in music. Soon, however, William's interests turned to astronomy. He was propelled into the spotlight when he discovered Uranus in 1781, bringing along his sister as his assistant. Her work began with polishing telescope lenses and making calculations.

Eventually, William began working for the royal family and, with that, Herschel became the first paid female scientist in Britain. Her pursuits morphed into finding comets and nebulae as well as editing the work of former Astronomer Royal John Flamsteed. This included reviewing and correcting the information on some of his discoveries while adding 500 more of her own to an index.

After her brother's death in 1822, Herschel moved back to Germany and continued to help his son, John, pursue astronomical knowledge. She also worked on her collection of thousands of nebulae, for which she received a gold medal from the Royal Astronomical Society in 1828. She later received an honorary membership to the same society for her work, along with her contemporary and friend, Mary Somerville.

This lithograph shows Caroline Herschel in 1847, just a year before her death. G. BUSSE (PUBLIC DOMAIN)

This portrait depicts Maria Mitchell in the later part of her life. © NANTUCKET HISTORICAL ASSOCIATION

Maria Mitchell
1818–1889

Maria Mitchell not only became the first female astronomy professor in the U.S., but she was also the first person in America to discover a comet.

Mitchell, who was born in Nantucket, Massachusetts, was highly influenced by her parents, who believed in equal education for both sexes. Her father was an educator and amateur astronomer, and encouraged Mitchell to operate his observatory together at night, while she worked during the day as a librarian.

On Oct. 1, 1847, at the age of 29, she discovered the comet that would propel her to prominence. Known as Miss Mitchell's Comet, C/1847 T1 was a non-periodic comet. Others spotted it in the following days, but the immediacy with which Mitchell reported it to astronomical officials meant the comet bore her name.

She went on to become first woman elected to the American Academy of Arts and Sciences in 1848. She was also one of the first women elected to the American Philosophical Society and was selected as a fellow at the American Association for the Advancement of Science. She worked for what is now known as the U.S. Naval Observatory, calculating the positions of Venus. Mitchell became one of the first professors appointed at the newly established Vassar College, remaining there until retiring in 1889. During her life, she was a proponent of women in the sciences and heavily involved in political movements at the time, including the women's suffrage movement and the abolition of slavery.

Annie Jump Cannon
1863–1941

Annie Jump Cannon is known for classifying 350,000 stars and developing the Harvard system of spectral classification, which is still in use to this day.

Born in Delaware, Cannon was introduced to stargazing by her mother. She studied physics and astronomy at Wellesley College in Massachusetts. After graduating, she became focused on photography. But after the death of her mother in 1894, she dove back into the world of astronomy.

Annie Jump Cannon sits at her desk at the Harvard Observatory. SMITHSONIAN INSTITUTION ARCHIVES

Cannon enrolled as a special student at Radcliffe College (the women's college affiliated with the then all-male Harvard College), where she began work as part of a group known as "Pickering's women." These women were designated to conduct research and calculations under Harvard Observatory Director Edward Pickering, and were often referred to as "computers." Following in the footsteps of insightful contemporaries such as Williamina Fleming and Antonia Maury, Cannon began examining image plates of various stars. Her analysis of over 1,100 stars led her to refine a method of classification based on their colors (which are related to their temperatures). The mnemonic device "Oh! Be A Fine Girl — Kiss Me!" is now a well-known way to remember the OBAFGKM classes of the Harvard spectral classification. The work was eventually published in the *Henry Draper Catalogue* of classification and officially adopted by the International Astronomical Union in 1922.

The extensive work bolstered her career, earning Cannon the position of curator of observational photographs at Harvard, which led to many more discoveries of variable stars and novae. She also received a Ph.D. from Groningen University in the Netherlands — the first woman to do so — as well as an honorary doctorate from Oxford University, among many more achievements.

Today, her legacy lives on: In 1933, the American Astronomical Society established the Annie Jump Cannon Award for outstanding current and future potential research by a female postdoctoral researcher. It is given to a North American female astronomer within five years of receiving her Ph.D. Among the winners are scientists who have advanced our understanding of the life cycle of stars, gravitational lensing, and more.

Henrietta Swan Leavitt
1868–1921

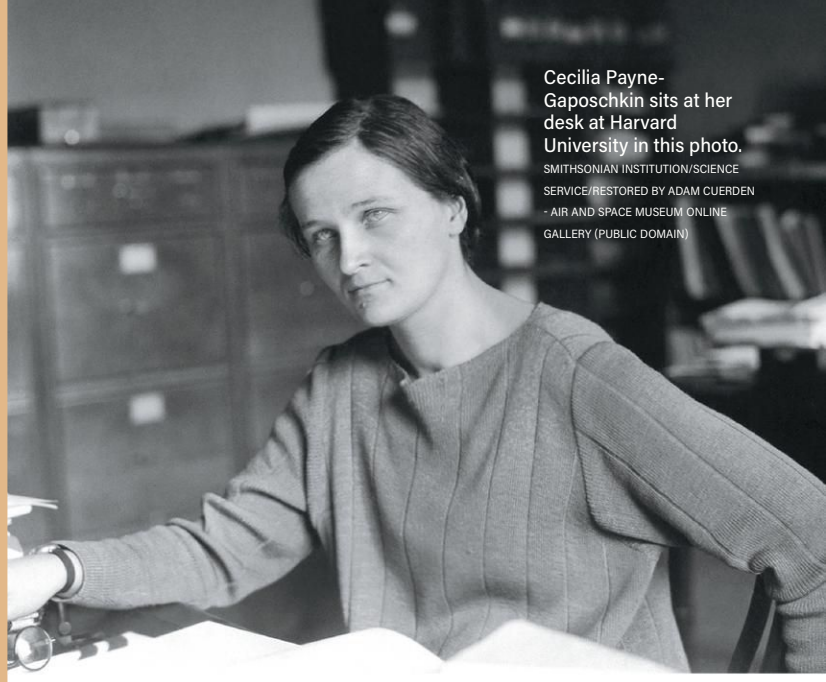
A relative unknown at her time of death, Henrietta Swan Leavitt was instrumental in the discovery of a relationship between the brightness and the period of Cepheid variables, a class of variable star that allows astronomers to determine distance in the universe.

Born in Cambridge, Massachusetts, Leavitt attended Oberlin College before transferring to Radcliffe College, where she studied languages, arts, and astronomy. There she took a route similar to Cannon's and began work for Pickering. Despite being highly educated, she worked as a volunteer in the position starting in 1895, before eventually becoming a paid employee in 1903. She was also not allowed to operate the telescope, which was exclusively reserved for men.

Part of her job was comparing variable stars. During her research, she noticed that the period over which a Cepheid variable star changed brightness directly related to the brightness of that star. (A brighter star has a longer period than a fainter star.) This became known as the period-luminosity relationship. It was later used by Edwin Hubble to conclude that Andromeda (M31) was in fact a faraway galaxy and not a nebula within the Milky Way. Unfortunately, Leavitt's position did not allow her to fully invest her time in these stars, and she eventually moved on to other tasks.

Leavitt died of cancer at 53, after experiencing many health problems throughout her life. Years later, researchers fully grasped the weight of her work and wanted to nominate her for a Nobel Prize. Unfortunately, this honor cannot be awarded posthumously.

This is one of the last photos taken of Henrietta Swan Leavitt, who died at 53 after suffering many illnesses throughout her life. EMILIO SEGRÈ VISUAL ARCHIVES, SHAPLEY COLLECTION, PHYSICS TODAY COLLECTION, NIELS BOHR LIBRARY & ARCHIVES, AIP/PHOTOGRAPH, MARGARET HARWOOD



Cecilia Payne-Gaposchkin sits at her desk at Harvard University in this photo. SMITHSONIAN INSTITUTION/SCIENCE SERVICE/RESTORED BY ADAM CUERDEN - AIR AND SPACE MUSEUM ONLINE GALLERY (PUBLIC DOMAIN)

Cecilia Payne-Gaposchkin
1900–1979

The first recipient of the Annie Jump Cannon Award, Cecilia Payne-Gaposchkin was also the first person to discover that stars are primarily made up of hydrogen and helium — a finding that took years to be acknowledged by the scientific community.

Born in Wendover, England, Payne-Gaposchkin was an active student. She attended Cambridge University with an interest in science but was unsure of what to focus on. There, she met astronomer Arthur Eddington, who — after she bombarded him with an onslaught of questions — gave her access to professional astronomical journals. Thus, her career in astronomy began.

Payne-Gaposchkin pursued her advanced degree at Harvard under the guidance of Harlow Shapely, Edward Pickering's successor. Like Cannon and Leavitt, she looked at the spectra of stars, but also took up the study of quantum physics. During these studies, she ultimately confirmed the idea that varying star colors are due to the stars' temperatures. She also showed that differences in stellar spectra are not due to disparate chemical composition in stars — which was the accepted theory at the time — but due instead to differing temperatures. Thus, stars are all mostly made of the same elements: hydrogen and helium.

In 1925, her doctoral dissertation asserted these findings, which were soon deemed "clearly impossible" by Princeton University Professor Henry Norris Russell. She was forced to downplay her work. Only later did others come to the same conclusion, and astronomers Otto Struve and Velta Zebergs said hers was "the most brilliant Ph.D. thesis ever written in astronomy."

Despite this hitch in her early career, Payne-Gaposchkin continued to work as Shapley's assistant, teaching for some time before being officially appointed as a professor in 1956. The same year, she was designated chair of the Harvard astronomy department.

Nancy Grace Roman
1925–2018

Nicknamed the "Mother of Hubble," Nancy Grace Roman spent years pushing for the use of the newest technology to better understand the universe.

Roman was born in Nashville, Tennessee. She was always interested in looking up at the stars and spearheaded an astronomy club in seventh grade. Despite being dissuaded from the subject during high school, she earned her bachelor's degree in astronomy from Swarthmore College and her Ph.D. from the University of Chicago.

After working at the latter for six years, she found that tenure was nearly impossible for women and made her way to NASA in 1959, just a few months after the agency's establishment. In 1961, she became the first chief of astronomy. At that time, balloons, sounding rockets, and airplanes were used for high-elevation observations — but Roman wanted an observatory that would live in space indefinitely. She had her heart set on creating a space telescope.

For years, Roman rallied for funding for this technological feat with Congress, conferring about science objectives before the scope was approved in 1977. She temporarily worked as a consultant while taking time off to care for her mother in 1979, before coming back to work at NASA's Goddard Space Flight Center's Astronomical Data Center. Although she was no longer associated with the development of the Hubble Space Telescope on a day to day basis, she was never far from it, keeping up to date on its progress until its launch in 1990. She retired from NASA officially in 1997 and became a schoolteacher in Washington, D.C.

After her death, NASA announced their next flagship scope would be the Nancy Grace Roman Space Telescope. When it is launched in May 2027, the infrared telescope will explore dark energy, exoplanets, and more.

Nancy Grace Roman, shown here at NASA's Goddard Space Flight Center in 1972, was the first female executive and the first chief of astronomy at NASA. NASA

Vera Rubin
1928–2016

Vera Rubin is best known for her discovery of dark matter — the strange substance that makes up roughly 85 percent of the known universe.

Rubin was born in Philadelphia, Pennsylvania, and was science-minded from the beginning. She received a scholarship to attend Vassar College and then went on to earn her master's degree in astrophysics at Cornell University. She attended Georgetown University for her Ph.D., where she eventually taught astronomy courses.

Her research went into high gear after she received a posting at the Carnegie Institution. The institution was working on extremely high-powered spectrographs to study ever-farther and tinier galaxies. In the 1970s, she and her colleague, Kent Ford, discovered that the stars within a galaxy are all moving at the same speed, regardless of their location in the core or outer edges. She concluded that this was impossible — unless there was something gravitationally binding the farther-out stars to the galaxy. They concluded it had to be some kind of unseen, "dark" matter, providing compelling evidence for the theoretical dark matter suggested by astronomer Fritz Zwicky some 30 years prior. But despite the fact that the two had observed over 60 galaxies to reach this conclusion, for some time the scientific community remained skeptical.

The challenge of dark matter, even to this day, is that it cannot be seen, yet we now know it makes up much of the universe. The Vera C. Rubin Observatory in Cerro Pachón, Chile, hopes to change that. Seeing first light in 2025, this observatory will include the largest digital camera ever built and the ability to study the southern sky in unprecedented detail by using gravitational lensing to identify dark matter.

In 1981, Rubin was elected to the National Academy of Sciences, and she received the National Medal of Science in 1993 along with other awards. Despite the recognition, for Rubin, that was never her goal. Throughout her life she simply enjoyed the search for strange and unexplainable phenomena within the universe.

Vera Rubin operates the No. 1 36-inch telescope at Kitt Peak National Observatory in 1963. Kent Ford's Image Tube Spectrograph is attached to the telescope. KPNO/NOIRLAB/NSF/AURA

Carolyn Shoemaker
1929–2021

Carolyn Shoemaker identified many asteroids and comets, including the famous Comet Shoemaker–Levy 9. But her path to achieving this was not a linear one.

Shoemaker was born in Gallup, New Mexico, and grew up in Chico, California, where she attended college for political science, literature, and history. However, after meeting the man who would eventually become her husband, her interest in science grew. After Gene Shoemaker received his doctorate at Princeton University, they moved and raised their three children in Flagstaff, Arizona.

As her kids got older, Carolyn continued her pursuit of knowledge first with geology and later astronomy, working as a research assistant to her husband on the Palomar Asteroid and Comet Survey at the Palomar Observatory in San Diego. In the search for new asteroids, she would examine the images under a stereo microscope. One day in 1993, while working with her husband and amateur astronomer David Levy, she discovered a streak near Jupiter in an image of the planet. It was unlike anything they had witnessed before. It turned out to be a comet that had come too close to Jupiter, breaking up into several fragments and now orbiting the planet. In honor of its discoverers, the comet became Comet Shoemaker–Levy 9. Eventually, the comet fragments plunged into Jupiter's atmosphere, the first event of this kind ever observed.

Carolyn discovered 39 comets in total, the highest at the time. She received many accolades for her work, including an honorary doctorate of science from Northern Arizona University. The asteroid 4446 Carolyn was named in her honor.

Gene and Carolyn Shoemaker sit at Palomar Observatory in 1994. U.S. GEOLOGIC SURVEY

Jocelyn Bell Burnell
Born 1943

The first person to notice signals coming from rapidly spinning neutron stars, Jocelyn Bell Burnell discovered pulsars in the 1960s, which has had far-reaching implications for radio astronomy to this day.

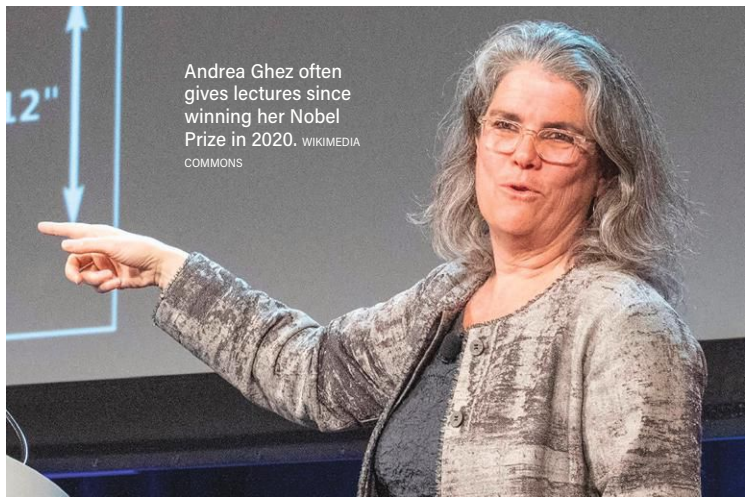
Born in Belfast, Northern Ireland, Bell Burnell quickly became a voracious reader, including in the sciences, despite her school's ban on science classes for girls. She attended the University of Glasgow before getting her Ph.D. in physics at the University of Cambridge.

During her time at Cambridge, she helped build the Interplanetary Scintillation Array, a radio telescope that assisted in her study of quasars (extremely luminous centers of galaxies, which house feeding supermassive black holes). One day, she noticed strange radio signals in her data. She and her superior thought it might be an issue with the telescope, as the signals weren't always apparent and unlike anything they had seen before. But it was not an equipment malfunction, and they determined the pulses were coming from neutron stars, now known as pulsars. Although this revelation was enough to be acknowledged by the Nobel Prize committee, she did not receive the prize because she was a graduate student at the time. Instead, it went to her advisor, Antony Hewish, and astronomer Martin Ryle.

Jocelyn Bell Burnell delivers the keynote address for Science and Technology for Development panel for UN Trade and Development Conference in 2019. JEAN-PHILIPPE ESCARD OF UNCTAD

Bell Burnell, however, was undeterred. She went on to win several awards throughout her career, including the Special Breakthrough Prize in Fundamental Physics in 2018 for her discovery of pulsars. She used the $3 million prize to start the Bell Burnell Scholarship Fund to promote greater diversity within the field of physics. She also continued working at many universities across the U.K. for several years. Now she gives speeches encouraging women to never give up.

Andrea M. Ghez
Born 1965



Andrea Ghez often gives lectures since winning her Nobel Prize in 2020. WIKIMEDIA COMMONS

Andrea Ghez received the Nobel Prize in physics in 2020 for her study of the supermassive black hole at the center of our galaxy. She is one of only five women to ever receive this award.

Born in New York City, Ghez saw the first lunar landing on television and decided to become an astronaut. Although her plans did change, she kept astronomy in mind as she went on to study physics at MIT before receiving her master's degree from Caltech. After graduating, she came to work at the University of California, Los Angeles, where she is a professor of physics and astronomy.

While at UCLA, Ghez and her colleagues began using the W.M. Keck Observatory telescope and adaptive optics to observe the center of the Milky Way at infrared wavelengths. This allowed them to cut through dust-obscured areas, targeting a group of stars in the constellation Sagittarius. They found stars moving at high speeds around a single, compact point. This point is Sagittarius A*, the Milky Way's central supermassive black hole and the closest such object to Earth.

For their breakthrough, she and Reinhard Genzel, a professor at University of California, Berkeley, were jointly awarded half the 2020 Nobel Prize, while the other half went to Richard Penrose, a professor at University of Oxford, for separate work on black holes. Ghez has also won numerous other awards and continues to discuss her work in talks and documentaries.

Ghez sums up the impact winning that prize in her UCLA bio: "To me, it's always been very important to encourage young women into the sciences, so to me the Nobel Prize means an opportunity and a responsibility to encourage the next generation of scientists who are passionate about this kind of work into the field."

Samantha Hill *is editorial assistant of* Astronomy *magazine and a female amateur astronomer.*

Is there a female astronomer who inspired you who was not included on this list? Write to **astronomyeditorial@astronomy.com** to let us know.

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Spectacular supernovae

These stellar explosions will blow your mind.

ABOVE: The author captured the Crab Nebula with her 8-inch Celestron Schmidt-Cassegrain using narrowband Hydrogen-alpha and Oxygen-III filters and 34 hours of total exposure time. MOLLY WAKELING

RIGHT: The author imaged the Veil Nebula with her Rokinon 135mm f/2 camera lens and a dual-narrowband (Hydrogen-alpha and Oxygen-III) filter in June 2022, with 6.5 hours of total exposure time. MOLLY WAKELING

BY MOLLY WAKELING
Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.

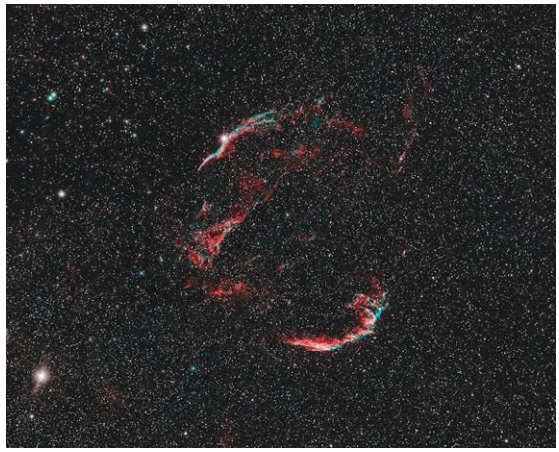
The universe is full of extreme phenomena. Perhaps this is what draws some people to astronomy — it has some of the most extreme physics out there. And supernovae are some of the most extraordinary objects that also have the benefit of being visible to astronomers here on Earth, even long after the explosive event itself.

An incredible amount of energy is involved in a supernova explosion. When I was preparing a talk on how all the elements are made for the 2018 Texas Star Party, I came across a figure for how much energy is output from a single supernova: 10^{44} Joules (J). A 1 followed by 44 zeroes is an enormous number — 100 million trillion trillion trillion. I wanted to translate that to a somewhat more comprehensible number: How many nuclear bombs is that? The bomb dropped on Hiroshima during World War II was 15 kilotons (kt); 1 kt is about a trillion joules (10^{12} J) of energy, so one Hiroshima detonation is about 10^{13} J. This means that one supernova is equivalent to 10^{31}, or 10 million trillion trillion Hiroshima detonations.

One supernova is equivalent to 10 million trillion trillion Hiroshima detonations.

This figure blew me away. Even more incredible is that this represents the kinetic energy of the ejected particles alone — neutrinos carry away another 10^{46} J. As bright as they are, sometimes outshining their host galaxies, the light output from a supernova is only a small fraction of its total energy release.

Supernovae are bright enough that even those in other galaxies are often visible through amateur telescopes — sometimes visually, such as SN2023ixf in M101 in May 2023. I had the pleasure of seeing that one with my own eye through a 16-inch Dobsonian. With a camera, backyard observers can often spy supernovae in galaxies tens of millions of light-years away. In fact, many supernovae are discovered by amateurs.



Even when there's not a new stellar explosion in the sky, there are several ancient supernova remnants to explore. Most easily visible in amateur scopes is the Crab Nebula, or M1, located in Taurus. The supernova was recorded by several societies in 1054 C.E. when it was visible during the day for three weeks, and only faded from nighttime skies two years later. The stellar core left behind is now a rapidly spinning neutron star known as a pulsar. It emits enough energy to light up the still-expanding cloud of stellar ejecta that surrounds it, making it visible as a fuzzy splotch at the eyepiece and in spectacular detail with a camera.

Another supernova remnant accessible to visual astronomers is the sprawling Veil Nebula (NGC 6960, among others) in Cygnus, also known as the Cygnus Loop. The star that created it 10,000–20,000 years ago was 20 times the mass of the Sun, and the supernova would have been visible during the day, outshining Venus. The still-glowing arcs of stellar material are best seen with a nebula filter under a dark sky — the Eastern Veil, Western Veil, and central Pickering's Triangle regions are breathtaking in my 16-inch Dobsonian with an Oxygen-III filter. Like the Crab, the Veil is also still expanding, at a rate of some 932,000 mph (1.5 million km/hr).

Supernovae have captured the imagination and delighted stargazers all over the world. Both recent and ancient supernovae are worth exploring with a telescope. Perhaps you'll discover the next one!

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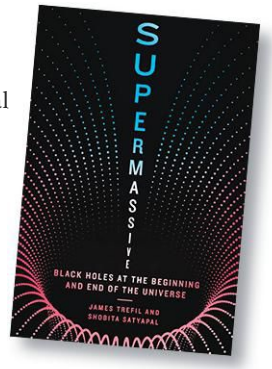

Physicist James Trefil and astrophysicist Shobita Satyapal shine a light on the mysterious world of black holes in their book *Supermassive*. The authors discuss everything from early research by Albert Einstein to how the current science on the topic is progressing, and even how these dark stars became an influence in science fiction.

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Messier's 102nd object

Some astronomers think that galaxy NGC 5866 in Draco, sometimes called the Spindle Galaxy, may be the true identity of M102. NASA, ESA, HUBBLE HERITAGE PROJECT (STSCI, AURA. ACKNOWLEDGMENT: WILLIAM KEEL (UNIVERSITY OF ALABAMA)

Q MESSIER'S 102ND ENTRY IS KNOWN AS THE LOST MESSIER OBJECT. HAS THERE BEEN ANY AGREEMENT ON WHAT THIS M OBJECT MIGHT BE?

William Shackelford
Bangor, Maine

A Before Charles Messier handed in the final supplement of his catalog, which was published in 1781, his contemporary, Pierre Méchain, supplied a number of new objects for his consideration. Messier observed all but three of them before his publishing deadline; still, he appended these three unseen objects as numbers 101, 102, and 103 to the supplement.

After the supplement was printed, Méchain published a letter of correction saying that M102 is "nothing but an error. This nebula is the same as the preceding No. 101. In the list of my nebulous stars communicated to him M. Messier was confused due to an error in the sky-chart."

What's more, two positions of M101 do exist. The 1781 position of M101 places it 1¾° to the west of its modern position. It also places M101 a mere 40' from the 6th-magnitude star 86 Ursae Majoris. This, of course, would explain why Messier, in his description of what he thought was M102, writes, "Close to it is a sixth-magnitude star."

On the other hand, the 1781 position of M101, when converted to modern coordinates, differs from the one in the NASA Extragalactic Database by a mere 1 arcminute. This could be the position of M101 published in Messier's catalog to which Méchain referred.

Despite Méchain's letter and that the above research provides a viable solution to the mystery, others believe that Méchain's observation of M102 best describes spiral galaxy NGC 5866. On the SEDS website (www.messier.seds.org/m/m102d.html), Hartmut Frommert presents an equally intriguing argument for NGC 5866 to be M102. The full article and a supplement are well worth reading, and I encourage you to do so.

Stephen James O'Meara
Contributing Editor

Q DO BLACK HOLES EXIST FOREVER? IF NOT, HOW DO THEY DIE? IF YES, IS THE NUMBER OF BLACK HOLES IN THE UNIVERSE ALWAYS INCREASING?

Eliot H. Ginsberg
Riverview, Florida

IN 1974, STEPHEN HAWKING PROPOSED THAT IN FACT, BLACK HOLES DO EVAPORATE.

A Black holes are known for their voracious appetites, consuming everything — even light — that falls inside them with no hope of escape.

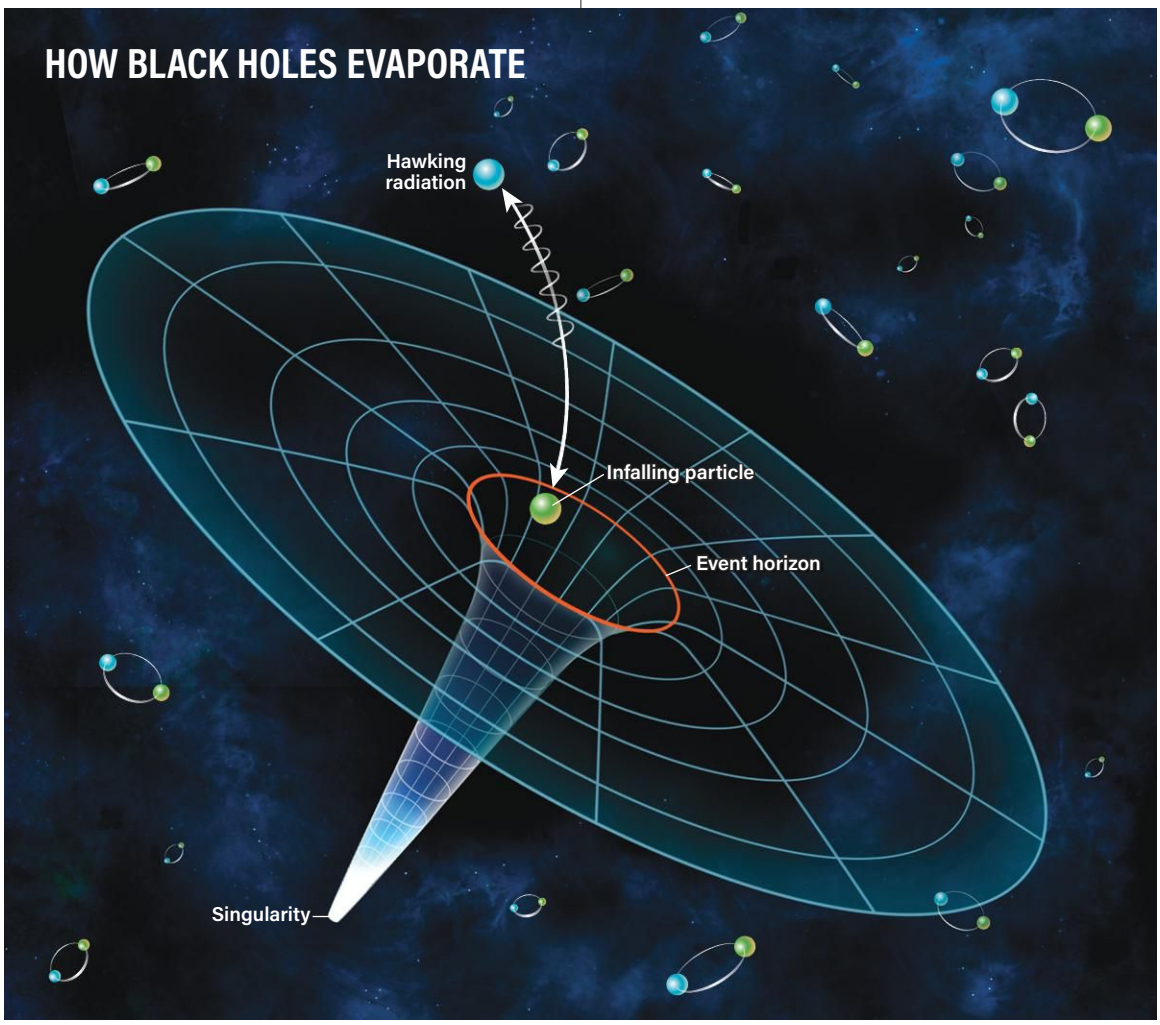
But in 1974, Stephen Hawking proposed that in fact, black holes do evaporate.

Everywhere, all the time, infinitesimal particles are popping into and out of existence. They appear in pairs that instantly annihilate each other. (Thank quantum mechanics for this weirdness!) But right at the event horizon, the black hole's point of no return, sometimes one particle in a pair will fall into the black hole and disappear. Its partner, then, would zoom away — meaning the black hole has emitted energy, and grown smaller.

Hawking reassures readers that it would take far longer than the age of the universe for this to completely evaporate even a solar-mass black hole. But what about tiny, primordial black holes?

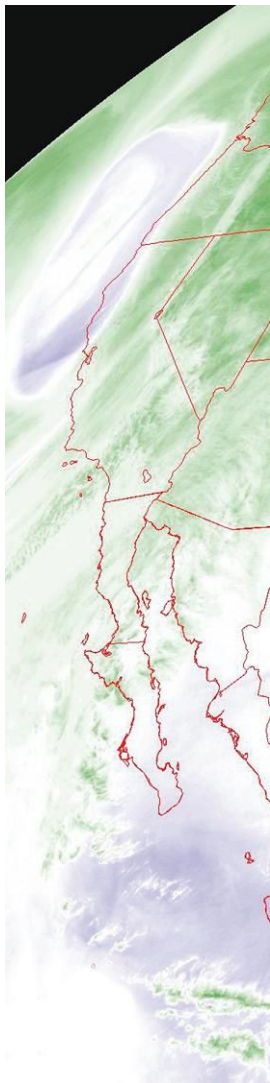
They could indeed evaporate entirely, and the process is one that speeds up as it progresses, leading to a large burp of energy in the black hole's final moment. In Hawking's own words: "This is a fairly small explosion by astronomical standards but it is equivalent to about 1 million 1 Megaton hydrogen bombs."

Korey Haynes
Contributing Editor



Hawking radiation, proposed by Stephen Hawking, could cause black holes to slowly evaporate over time. Quantum fluctuations in space-time can cause pairs of virtual particles to pop into existence, and then immediately annihilate each other and disappear again throughout the universe. But if such a pair appears right at the event horizon of a black hole, one particle could fall in while the other escapes, carrying away a minuscule amount of energy — and therefore mass — from the black hole.

ASTRONOMY: RICK JOHNSON & ROEN KELLY



Q I'VE LONG WONDERED WHETHER DEW POINT OR RELATIVE HUMIDITY IS MORE IMPORTANT FOR GOOD SEEING. WHICH WOULD BE BETTER: A COOL NIGHT WITH LOWER DEW POINT BUT HIGHER HUMIDITY, OR A WARM NIGHT WITH HIGHER DEW POINT BUT LOWER HUMIDITY?

William Shepard
Troy, Michigan

A Dew point/relative humidity questions come up fairly often and this is a good one. Water vapor in the atmosphere is pretty important for deep-sky observing and photography.

The atmosphere can only hold a finite amount of water before it becomes full, or saturated. That amount is somewhat flexible (it is possible to be oversaturated), but that definition is good for our purpose here. The problem is that the amount of water a sample of air can hold depends on temperature.

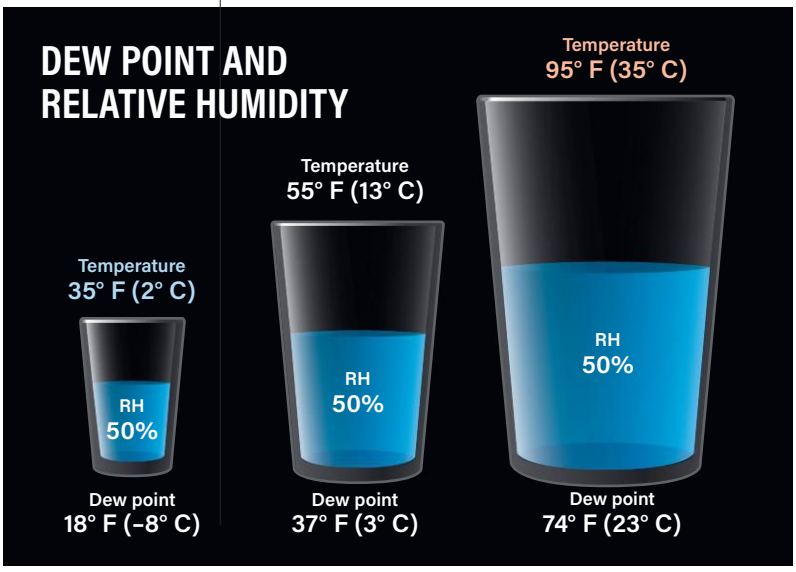
Relative humidity (RH) is a comparison between the actual amount of water in the atmosphere and how much would be needed to saturate it. If you have 80 percent RH, then the air is holding 80 percent of the water that it could — at that temperature. It's kind of like a bucket that's 80 percent full at one temperature, except that the bucket would grow larger as the temperature goes up and shrink when it falls. The amount of water wouldn't change.

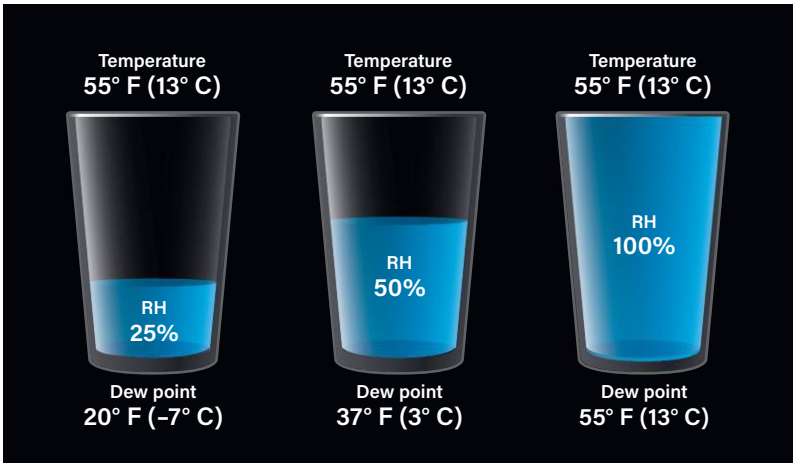
Dew point is the temperature at which the moisture in the air would condense and, supposedly, form dew (or frost) on a telescope. To belabor our example, it's the point at which falling temperatures would shrink our bucket to the point where the contents overflowed. In practice, dew point is a more stable measurement of water in the atmosphere. It measures the absolute amount of water rather than the relative amount of water.

For example, a sample of air that is saturated at 40 degrees Fahrenheit (4 degrees Celsius) and one that is saturated at 78 F (26 C) both have a relative humidity of 100 percent, but the sample at the higher temperature has 3½ times as much water as the colder sample. Both are filled when saturated, but one contains much more water.

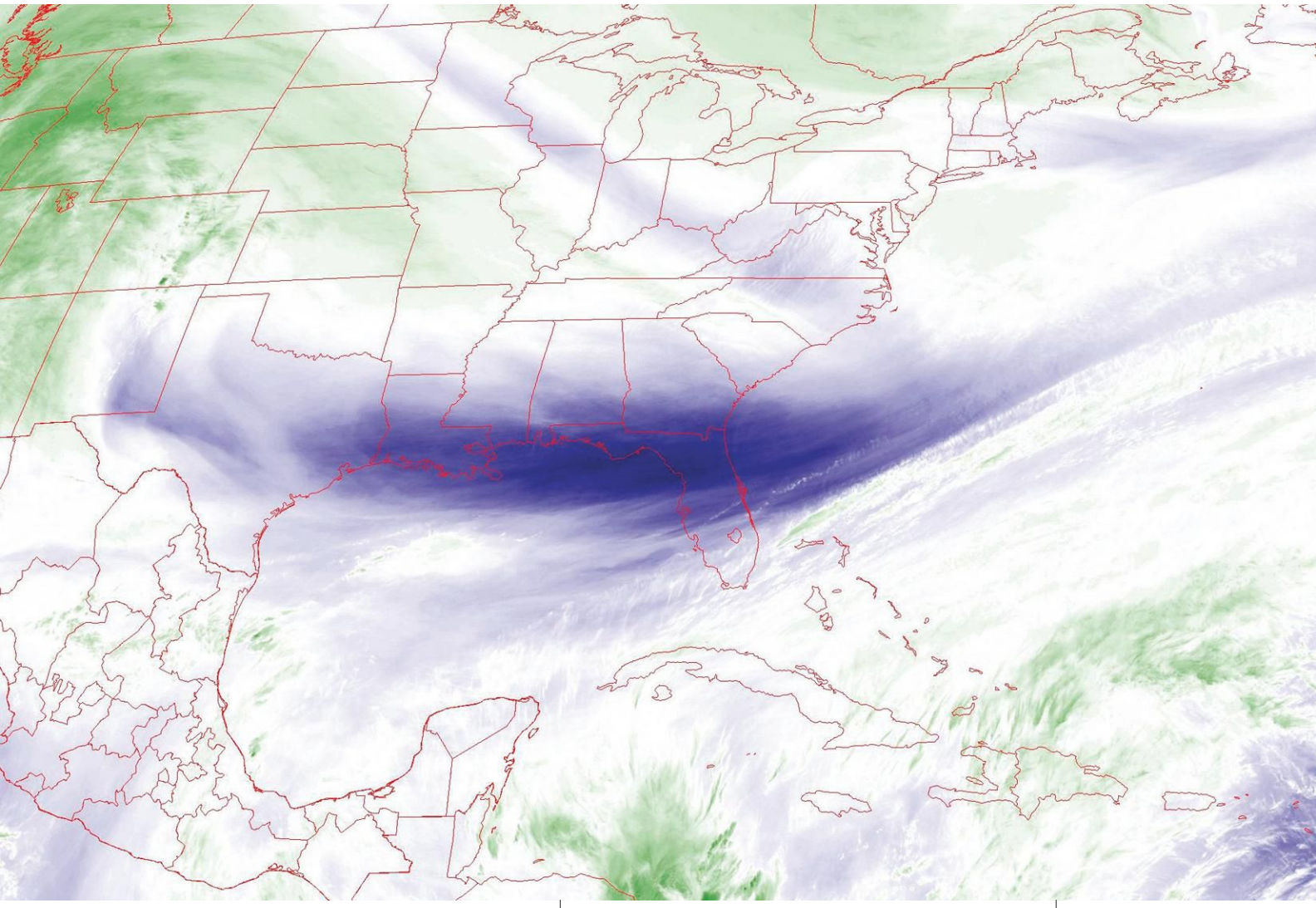
Now consider the dew point: Let's say both samples are in same-sized buckets and have a dew point of 32 F (0 C). That's a relative humidity of 73 percent for the cooler sample and 23 percent for the warmer. Both will reach condensation at the same temperature. And, at 32 F (0 C), air has a "moisture content" of 0.09 pound per square inch (0.006 kilogram per square centimeter), or 6.11 millibars. Those look like strange numbers, but that's because moisture content is usually expressed as vapor pressure — the pressure that the water molecules contribute to the total atmospheric pressure. The units don't matter; what matters is that the number is the same for both samples. In other words, they both have the same amount of water vapor, and if our two buckets were cooled to very cold temperatures, they would have the same amount of ice on the bottom.

So, dew point is a proxy measure of the actual amount





Relative humidity (RH) measures the amount of moisture in the air compared to the amount of total moisture the air can hold at a given temperature — for example, 55 F (13 C), as shown in the bottom panel. This affects the dew point, which equals the air temperature when RH is 100 percent. Dew point is an absolute measure of how much moisture is in the air at a given time. For a given RH (say, 50 percent, as in the top panel), warmer air can hold more moisture overall, which causes the dew point to rise.
ASTRONOMY: ROEN KELLY, AFTER NOAA/NWS



This view from the GOES-East satellite's band 8 shows the atmosphere above the continental U.S. imaged at 6.2 microns, in the infrared portion of the spectrum, at midday on Jan. 3, 2025. Images at this wavelength show water vapor in the upper troposphere. Red and yellow colors indicate dry air (not present here), blue indicates moist air, and white and green colors show clouds. NOAA/NESDIS/STAR

of water in the air (by weight or pressure), while relative humidity is a measure of the fractional amount of vapor.

Winter and summer nights often have relative humidities that reach close to 100 percent by morning, if not well before. Yet, winter nights are often brilliantly clear while summer nights can be hazy. Dew point is better at telling you when your optics will acquire a coating of moisture, since your telescope is usually colder than the air around it and the dew condenses first where it's least wanted. If you have a regulated dew heater, you want to measure what's up against the telescope, not what's in the air around you.

However, from an observational point of view, it's not the water near the ground that's the problem, it's the total amount of water vapor above you. To assess that, I look at the water vapor satellite images that are available online, such as at https://weather.cod.edu/satrad, for instance. There are several choices of water vapor image, but I like the high-level one. Just check the image before you go out observing and see if there's a dry area in the upper atmosphere that's coming toward you. If so (and it's otherwise clear), plan on doing your best photography or reaching for the faintest objects that night. You might also plan on using a dew heater, because low water vapor content means that the night will cool quickly. If you are a planetary observer or photographer, high relative humidity (or dew point) near the ground (in Florida, for instance) may be an indication that the air is under an inversion and stable and the seeing is superb, so it's not always one or the other. Most observers know that nights with thin fog are often the best for teasing out detail in Mars, Jupiter, or Saturn.

So, to answer the question, it really depends on what's going on higher up in the atmosphere, but a lower dew point is a better starting point for good observing. In reality, both cool and warm nights will reach near 100 percent RH at some point, but the colder air would contain less water.

Jay Anderson
Meteorologist, Winnipeg, Manitoba

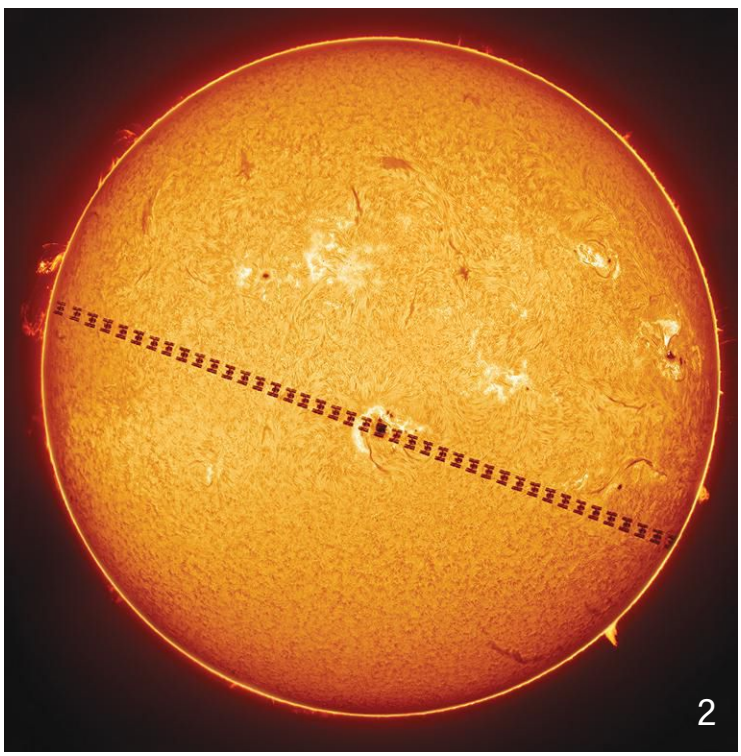
SEND US YOUR QUESTIONS

Send your astronomy questions via email to **askastro@astronomy.com**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

1. SEEN ON HIGH
The Angel Nebula (NGC 2170) lies in Monoceros and features the red hues of hydrogen, as well as reflected blue light from young, hot stars. The imager took nearly seven hours of exposure with a one-shot color camera on a 6-inch scope.
• ***Emmanuel Delgadillo***

2. ON STATION
Prominences dance around the limb of the Sun as the International Space Station crosses in front of the disk, imaged here in Hα with a 3.2-inch solar telescope.
• ***Shakeel Anwar***

3. STARRY SIDE UP
These "deviled egg" rock formations — also called the "Alien Eggs" — lie under the Milky Way near Bisti, New Mexico. This panorama was taken with an astromodified Nikon Z 6II and 14–24mm zoom lens, capturing the sky with four exposures of 180 seconds at f/3.2 and ISO 800.
• ***Abhijit Patil***



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4. BIRD OF PREY
The dust clouds in this field near the border of Libra and Ophiuchus take on the appearance of an eagle, with a bright star (HD 142269) as its eye. The brighter emission in this field is associated with LBN 10, and the darker clouds — especially around the eagle's head — comprise LDN 134. This image represents 16.8 hours of exposure with a 5-inch scope in LRGB filters.
▪ ***Santiago Ramos Avila***

5. NEARBY PLANETARY
Sharpless 2–216 is one of the closest planetary nebulae to Earth, just 415 light-years away in Perseus. On the sky, it has a diameter three times larger than that of the Full Moon. At left lies emission nebula LBN 755. This image comprises over 53 hours of exposure with a 2.8-inch scope in Hubble-palette filters, plus 30 minutes of RGB data. ▪ ***Emmanuel Joly***

SEND YOUR IMAGES TO: readergallery@astronomy.com.
Please include the date and location of the image, your mailing address, and complete photo data: telescope, camera, filters, and exposures.

6. A GALACTIC TAPESTRY
Lying 240 million light-years away, the members of the Perseus Galaxy Cluster shimmer in this deep-field portrait, mingling with delicate foreground wisps of hydrogen and cirrus in the Milky Way. This composite represents 392 hours of total exposure time (roughly split between Hα and LRGB) captured by 19 imagers using telescopes ranging from 2.7 to 11 inches in aperture.

• Overall Photons: Elisa Cuccu/Andrea Iorio/Fernando Linsalata/Giampiero Lilli/Roberto Volpini/Gianni Melis/Roberto Testi/Stephane Moinard/José Manuel López Arlandis/Michele Mazzola/Vitali Pelenjow/Leonardo Pelosi/Patrick Bisaillon/Aidan Guerra/Jeff Ratino/George William Hoffman/Vasile Unguru/Vakhtang Khutsishvili/Jonathan Schwab

7. ALL AGLOW
The Milky Way, zodiacal light, and airglow are all visible in this all-sky mosaic, representing phenomena on planetary, solar system, and galactic scales. The scene was captured with an astromodified Sony mirrorless camera, 11mm lens, and 20-second exposures at f/2.8 and ISO 20000 from a plateau lake in Gangzi, Sichuan Province, China.
• Huang Dandan

8. A TRIO IN AURIGA
Auriga the Charioteer is home to a close trio of iconic nebulae (from left to right): IC 417 (the Spider Nebula), IC 410 (home of the Tadpoles), and IC 405 (the Flaming Star Nebula). The imager used a 3.5-inch scope to obtain 29⅓ hours of exposure, the bulk of which was taken with dual-band filters (Hα/OIII and SII/OIII). ***• Andrea Arbizzi***

CASTING A WIDE WEB

The Orion Nebula (M42) and Carina Nebula (NGC 3372) may reign supreme among star-forming regions in the Milky Way, but they pale in comparison to the Tarantula Nebula (NGC 2070). The Tarantula resides in the Large Magellanic Cloud, a satellite galaxy to our own located 160,000 light-years away. This nebula spans roughly 1,000 light-years and contains nearly a million stars, dozens of which weigh more than 100 Suns. And the Tarantula holds enough gas to forge hundreds of thousands of future stars. The Hubble Space Telescope captured this tiny section on the nebula's outskirts, southeast of the central R136 cluster. Hubble took the image through filters sensitive to ultraviolet, visible, and near-infrared wavelengths. Colorful stars, billowing gas clouds, and thick dust dominate the region. Many of the stars appear reddish because dust absorbs and scatters blue light more effectively than red. ESA/HUBBLE & NASA, C. MURRAY

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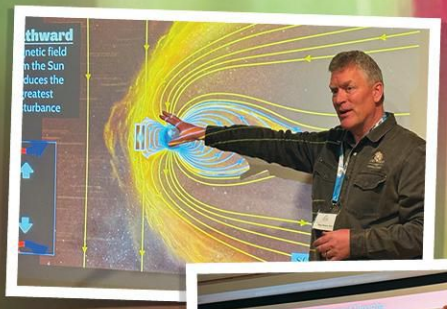

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July 2025
Mercury rules at dusk

It doesn't happen often that **Mercury** ranks as the planetary highlight of the evening sky, but July is an exception. The solar system's smallest major planet reaches greatest elongation July 4, when it lies 26° east of the Sun and stands 11° high in the northwest an hour after sunset. Mercury shines at magnitude 0.5, making it an easy target in the gathering twilight.

Take some time each evening to observe the innermost planet through your telescope. The first half of July finds Mercury drawing closer to the Sun, so we see more of its night side and thus a pleasing crescent phase. The inner world also is approaching Earth, so it grows larger in the eyepiece. On July 1, Mercury appears 7.6" across and 46 percent lit. On the 15th, it spans 9.9" and the Sun illuminates 22 percent of its Earth-facing hemisphere. The planet disappears in the Sun's glow in late July.

Unlike Mercury, **Mars** remains on view all month. The Red Planet drifts slowly eastward through Leo during July, crossing into western Virgo in the month's final days. Mars glows at magnitude 1.5 and appears more conspicuous for its ruddy color than for its brightness. A telescope reveals a disappointing sight: a featureless disk only 5" across.

Only an hour or so after Mars sets in the west, **Saturn** rises in the east. The ringed planet lies against the backdrop of southern Pisces the Fish. Its eastward motion comes to a halt July 14, when it begins to move westward in anticipation of its September opposition.

The best views of Saturn through a telescope occur when it climbs high in the sky during the early morning hours. The planet shows an 18"-diameter disk surrounded by a ring system that spans 41" and tilts 3.6° to our line of sight. Also keep an eye out for Saturn's brightest moons: Titan, Tethys, Dione, and Rhea.

You can use Saturn as a guide for finding **Neptune** in early July. On the 1st, the ice giant planet lies 1.0° north of the ringed world. Neptune glows at magnitude 7.8 so it's bright enough to see through binoculars, though you'll need a telescope to capture its blue-gray hue.

Early risers can enjoy wonderful views of **Venus** in the northeast before daybreak. The planet shines at magnitude –4.1 among the background stars of Taurus, appearing 100 times brighter than the Bull's luminary, 1st-magnitude Aldebaran. The planet passes 3° north of the star July 14, but a better view comes the morning before when Venus appears nearly on top of Epsilon (ε) Tauri and marks the northern tip of the V-shaped Hyades star cluster. At month's end, the planet makes a brief and rare excursion into far northern Orion.

As Venus' orbit carries it away from Earth this month, the inner planet appears smaller and more fully illuminated through a telescope. It begins July sporting a disk 18" in diameter and 64 percent lit. By month's end, its disk spans 14" and appears three-quarters lit.

Jupiter remains lost in the Sun's glare in early July but climbs into view to the lower right of Venus after midmonth. Shining at magnitude –1.9, it easily pierces the twilight glow. Although a telescope shows the planet's 33"-diameter disk at month's end, poor seeing near the horizon will render details hard to see. Better views await in the coming months.

A waxing gibbous Moon occults 1st-magnitude Antares on July 7. Observers in the western parts of Western Australia, the Indian Ocean, and parts of South Africa can see this event. From Perth, Antares disappears at 19h24m UT (on the morning of July 8) and reappears at 20h19m UT.

The starry sky

Midwinter is a great time to observe the far southern sky. The spectacular Milky Way arcs high in the south, passing through Crux the Cross with Carina the Keel to its right and the Pointers (Alpha [α] and Beta [β] Centauri) in Centaurus the Centaur to its left.

Alpha Cen makes a fine telescopic object. The third-brightest star in the night sky quite easily resolves into a double star. The primary one is a near twin to the Sun, while the secondary is a bit smaller and cooler. A third member of the system, the 11th-magnitude red dwarf Proxima Centauri, lies some 2° away from the main pair. Proxima's main claim to fame is as the closest star to the Sun. Father Jean Richaud discovered the duplicity of Alpha Centauri from Pondicherry, India, in 1689. Robert Innes first spotted Proxima in 1915.

Surprisingly, perhaps, Beta Cen — whose proper name is Hadar — also is a triple system. Dutch astronomer Joan Voûte discovered Beta's main companion in 1935. Beta Centauri B lies 1.3" from the primary. Glowing at 4th magnitude, it's extremely hard to spot next to the magnitude 0.6 primary.

In the 1960s, observations of the primary showed variations in its light curve that suggested it was a member of a binary system, making Beta a triple system. To me, R.R. Shobbrook and J.W. Robertson wrote the most significant paper on the star's duplicity in 1968. They used the famous 74-inch telescope at Australia's Mount Stromlo Observatory, which was destroyed by devastating fires in 2003. I was reflecting on those observations last year when I attended the observatory's centenary celebration.

Through those observations and the work of many others, astronomers have established that Beta Centauri A is indeed a close double star. Both suns are blue-white giants that orbit each other every 357 days.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. July 1
8 P.M. July 15
7 P.M. July 31

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

JULY 2025

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

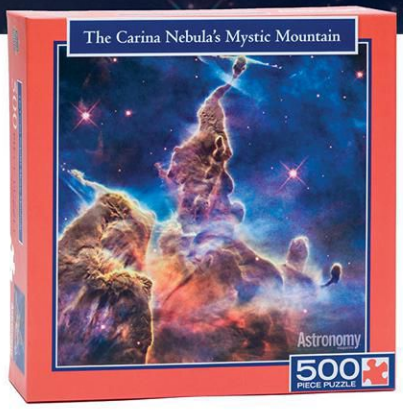
ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

2 First Quarter Moon occurs at 19h30m UT
3 Earth is at aphelion (152.1 million kilometers from the Sun), 20h UT
The Moon passes 0.8° south of Spica, 22h UT
4 Venus passes 2° south of Uranus, 1h UT
Mercury is at greatest eastern elongation (26°), 5h UT
5 The Moon is at apogee (404,627 kilometers from Earth), 2h29m UT
Neptune is stationary, 15h UT
7 The Moon passes 0.4° south of Antares, 18h UT
10 Full Moon occurs at 20h37m UT
11 The Moon passes 0.02° north of Pluto, 23h UT
14 Venus passes 3° north of Aldebaran, 4h UT
Saturn is stationary, 8h UT
Asteroid Juno is stationary, 10h UT
16 The Moon passes 3° north of Neptune, 10h UT
The Moon passes 4° north of Saturn, 11h UT
17 Mercury is stationary, 7h UT
18 Last Quarter Moon occurs at 0h38m UT
20 The Moon passes 5° north of Uranus, 13h UT
The Moon is at perigee (368,041 kilometers from Earth), 13h55m UT
21 The Moon passes 7° north of Venus, 19h UT
23 The Moon passes 5° north of Jupiter, 4h UT
24 New Moon occurs at 19h11m UT
25 Pluto is at opposition, 7h UT
26 The Moon passes 1.3° north of Regulus, 20h UT
28 The Moon passes 1.3° south of Mars, 20h UT
31 The Moon passes 1.0° south of Spica, 6h UT
Southern Delta Aquariid meteor shower peaks

EXPLORE THE UNIVERSE



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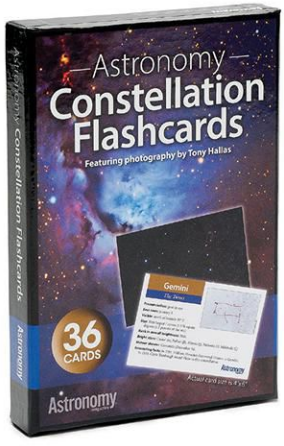

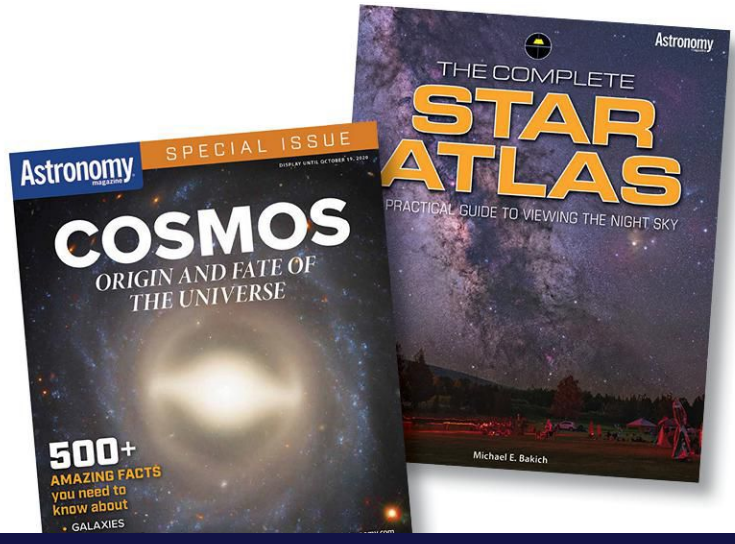

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